Distribution A.

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INTERFACE DOCUMENT

LIGHTING, AIRCRAFT, INTERIOR, NIGHT VISION IMAGING SYSTEM (NVIS) COMPATIBLE

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FOREWORD

MIL-L-85762A was published in 1988 and served very well for eight years as the standard definition and interface criteria for NVIS compatibility. This new document (ASC/ENFC 96-01) was derived from MIL-L-85762A in 1996 as a way to preserve this widely accepted standard definition, and to comply with the Perry directive. In compliance with the Perry directive, this document no longer contains the lighting system design requirements that were in MIL-L-85762; it now deals only with interface and performance requirements.

It is assumed that any contract for lighting equipment includes a Technical Requirements Document (TRD) that specifies the operational features of the lighting equipment. Such a TRD should reference ASC/ENFC 96-01 as the NVIS compatibility requirement when full compatibility between a specific class of NVIS and an aircraft cockpit is intended.

This document maintains exactly the same technical criteria for Class A and Class B NVIS compatibility as was required by MIL-L-85762. It is intended that once this document is in use and has been refined to meet a wide variety of users' needs, it will be re-published as a tri-service interface standard.

This document adds two new appendices that are very preliminary at this time, one defining the various classes of exterior lighting, and one explaining a new class of NVIS referred to as "leaky green" or green notch to allow for crewmembers to adequatly see the Head Up Displays.

INTERFACE DOCUMENT

LIGHTING, AIRCRAFT, INTERIOR, NIGHT VISION IMAGING SYSTEM (NVIS) COMPATIBLE

This document is approved for use by the Department of the Air Force and is available for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This document establishes performance, test and acceptance requirements for night vision imaging system (NVIS) compatible aircraft interior lighting (see 6.3.6). It is applicable to all systems, subsystems, component equipment and hardware which provide the lighting environment in aircraft crewstations and compartments where NVIS are employed. This document is applicable to NVIS specific performance requirements but does not contain lighting requirements. The contracting activity should extract and tailor applicable general lighting requirements from AFGS-87240 and MIL-STD-411 and include those requirements in the contract.

1.2 Purpose. The purpose of this document is to provide performance requirements and testing methodology to ensure effective and standardized aircraft interior lighting for NVIS compatibility.

1.3 Classification. Night vision imaging system (NVIS) compatible aircraft interior lighting addresses the following types and classes, as specified (see 6.2).

Type I — Lighting compatible with any direct view image NVIS (see 6.3.1.1) utilizing generation III Image intensifier tubes.

Type II — Lighting compatible with any projected image NVIS (see 6.3.1.2) utilizing generation III Image intensifier tubes.

Class A — Lighting compatible with NVIS utilizing 625 nm minus blue objective lens filters (see 6.3.1.3) with the specifications on figure 1.

Class B — Lighting compatible with NVIS utilizing 665 nm minus blue objective lens filters (see 6.3.1.4) with the specifications on figure 1.

2. APPLICABLE DOCUMENTS

2.1 General. The documents listed in this section are specified in sections 3 and 4 of this document. This section does not include documents cited in other sections of this

document or recommended for additional information or as examples. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements documents cited in sections 3 and 4 of this document, whether or not they are listed.

2.2 Government documents.

2.2.1 Specifications, standards and handbooks. The following specifications standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DoDISS) and supplement thereto, cited in the solicitation (see 6.2).

STANDARDS

DEPARTMENT OF DEFENSE

MIL-STD-461	Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference
MIL-STD-462	Electromagnetic Interference Characteristics, Measurement of
MIL-STD-1776	Aircrew Station and Passenger Accommodations

(Unless otherwise indicated, copies of the above specifications, standards, and handbooks are available from the Standardization Documents Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094.)

2.3 Order of precedence. In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. REQUIREMENTS

3.1 Description. This document defines the performance requirements and test procedures applicable to NVIS compatible lighting systems for new or modified aircraft lighting equipment and crewstations when specified in the weapon system design specification.

3.2 First article. When specified (see 6.2), a sample shall be subjected to first article inspection in accordance with 4.3.

3.3 Mockup. When required by the acquiring activity (see 6.2) a mockup of each lighting system shall be prepared by the contractor for inspection and approval prior to incorporation into production or redesigned aircraft, an aircrew station mockup shall

be prepared and made available by the contractor to ensure compliance with the NVIS compatibility and lighting system, subsystem or component requirements specified herein. Actual instruments, panels, paint, or uncoated structures shall be used. When inspected in accordance with 4.6.1 and 4.6.2 the aircrew station mockup shall conform to all of the requirements of this document as applicable. There shall be no evidence of degraded NVIS resolution in the presence of aircraft interior lighting.

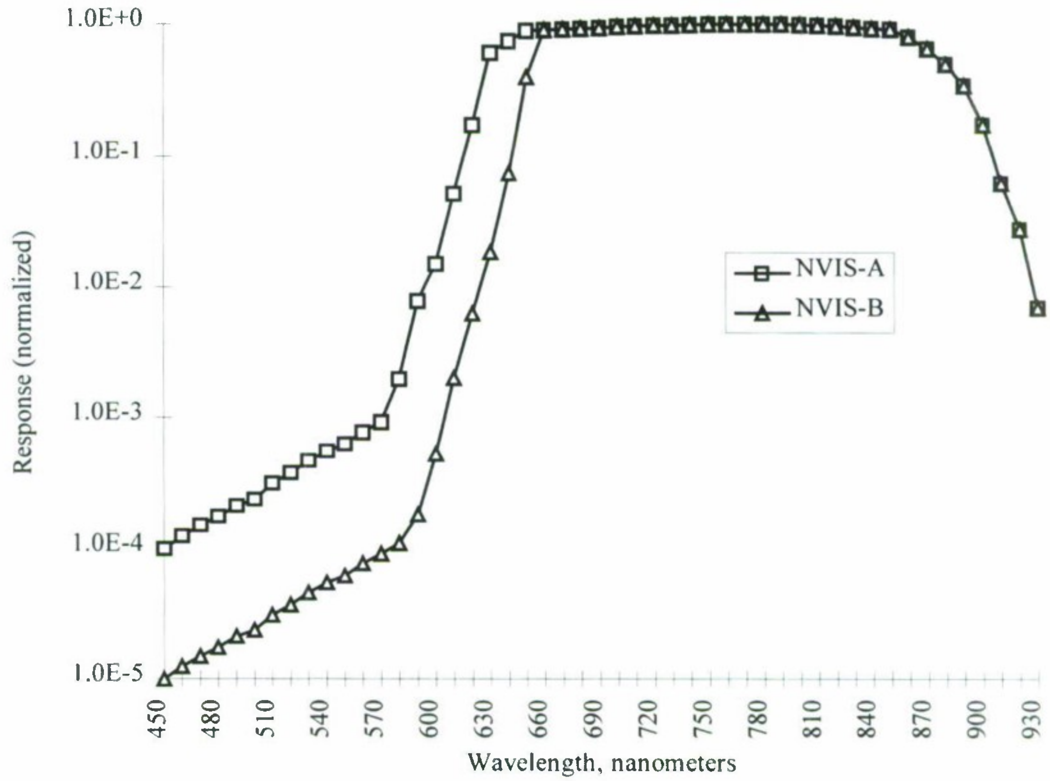


FIGURE 1. Relative spectral response characteristics of Classes A and B NVIS.

3.4 Installation. Lighting fixtures shall not be used as part of the pressure barrier. All lights shall be oriented and all components shall be so indexed or designed that the lights are properly aimed when replaced or reassembled after relamping.

3.4.1 Accessibility. Connectors shall be spaced far enough apart so that they may be grasped firmly for connecting and disconnecting. Space between adjacent connectors, or between a connector and any adjacent obstructions, shall be compatible with the size and shape of the plugs, and the type of clothing worn by the maintainer (for example, cold weather handwear, NBC gloves), but shall not be less than 25mm (1

inch), except where connectors are sequentially removed and replaced and 25mm (1 inch) clearance is provided in a swept area of at least 1.5 π rad (270°) around each connector at the start of its removal/replacement sequence. Spacing shall be measured from the outermost portion of the connector, i.e., from the backshell, strain relief clamp, dust cover or EMI/RFI shield. Where high torque is required to tighten or loosen the connector, space shall be provided for the use of a connector wrench.

3.5 System integration. The number of different types of lighting equipment, light sources, and power shall be kept to a minimum in any given aircraft installation. All lighting sources shall track together in luminance over the entire range of the lighting system

3.5.1 Lighting provisions. The design and location of the lighting equipment shall optimize visual performance and minimize the effects on NVIS. The lights shall not cause direct or indirect glare to interfere with the aircrew member's interior or exterior unaided vision and with the image intensification capabilities of the NVIS. Lighting equipment shall be so designed that: (1) prescribed ground and in-flight maintenance of the lamp can be accomplished without damaging or degrading the performance of the equipment; and (2) the lamps will give satisfactory service under the environmental conditions specified by the acquiring activity.

3.5.2 Light sources. Light sources shall meet all of the requirements herein, and shall be compatible with space, weight, and power constraints of the aircraft. Other issues which shall be considered in the selection of light sources are:

a. Design, production, support cost (i.e., life cycle costs)

b. Reliability

c. Operating efficiency

d. Heat generation

3.5.3 Lighting power. Unless otherwise specified by the acquiring activity, the lighting subsystem shall be designed to operate from a 5 V ac (400 Hz), 5 V dc, 28 V dc, or a 115 V ac (400 Hz) power source.

3.5.4 Lighting control location and actuation. Lighting controls shall be provided to allow each crewmember to control the intensity of all of the interior lighting subsystems that provide illumination for his crewstation. Lighting units related by function or area shall have common controls as required by the aircraft mission (for example, functionally related units such as flight instruments or navigation controls). An adequate number of controls shall be provided to allow the crewmember the flexibility to reduce glare, distractions, and fatigue.

3.5.4.1 Control panel location. Each crewstation shall be provided with a lighting control panel, convenient for operation by that aircrewmember for controlling all lights that are usually employed by that aircrew member only. For lights which are usually employed by two aircrew members, lighting control panel(s) convenient for operation by both of those aircrew members should be provided. Control panels shall be located to permit unaided eye viewing by an aviator wearing NVIS without requiring extreme head movements.

3.5.4.2 Identification. Each component shall be marked as follows: "NVIS Type ( ), Class ( )".

3.5.5 Compartment lighting. The design shall preclude inadvertent actuation of non-NVIS compatible lighting. This lighting shall allow the crew and passengers normal ingress and emergency egress within the aircraft interior. The lights shall not be a source of direct or reflected glare to aircrewmembers or be seen by outside observers. Lighting, as required by the acquiring activity (see 6.2) shall be provided for the cargo compartment, loading and ramp areas, passageways, passenger seating area and auxiliary power plant compartment. Chromaticity and spectral radiance limits shall be as specified in 3.6.7 and 3.6 8. Illuminance levels shall be as required in table I, unless otherwise specified by the acquiring activity.

TABLE I. General lighting for crewstations and compartments. 1/

	ILLUMINATED LEVEL IN FOOTCANDLES (AT RATED DRIVE CONDITION)	
	MIN	MAX
CREWSTATION AREA, GENERAL ILLUMINATION	1 (Aisle floor)	20 (Crew lap level)
CONTROL PANELS NOT ILLUMINATED (REQUIRING IN-FLIGHT ADJUSTMENT AND OPERATION)	5	10
INSTRUMENT PANEL AND CONSOLES	2	10
PASSAGEWAYS AND AISLES (ON FLOOR)	0.2	5
CARGO COMPARTMENT (ON FLOOR)	0.2	5
LOADING AND RAMP AREAS (ON FLOOR)	2	10
CREWSTATION LOCATIONS FOR NAVIGATIONAL AND SYSTEMS COMPUTATIONS TASKS (LIGHT ON WORK AREAS)	30	60
AUXILIARY POWER PLANT, ELECTRICAL AND ELECTRONIC COMPARTMENTS (LIGHT ON WORK AREAS)	5	10

1/ Continuous intensity control of the above lighting from full bright to 0.02% of full bright and "off" is required. The locations for these controls shall be approved by the acquiring activity.

3.5.6 Emergency exit lighting. Emergency exit lighting subsystems that may be automatically activated during flight shall meet the spectral radiance requirements in 3.6.8.7.

3.5.7 Crewstation controls and control handles. The lighted color and spectral radiance limits for illuminated controls shall be as specified in 3.6.7.3 and 3.6.8.3.

3.5.8 Caution and advisory signals. The location shall permit unaided eye viewing by an aviator wearing NVIS without extreme head movement. Chromaticity limits shall be as specified in 3.6.7.6 and the NVIS radiance requirements shall be as specified in 3.6.8.6.

3.5.9 Jump lights. The NVIS radiance of jump lights shall be as specified in 3.6.8.7 and chromaticity limits shall be as specified in 3.6.7.7. Different geometric shapes and sizes may be used to distinguish the "caution light" from the "jump light" when viewed through the NVIS. The specific geometric shape designs shall be approved by the acquiring activity.

3.5.10 Work and inspection lights. When provided as part of the aircraft, work and inspection lights shall meet the chromaticity and NVIS radiance limits specified in 3.6.7.5 and 3.6.8.5.

3.6 Performance.

3.6.1 Daylight legibility and readability.

3.6.1.1 Illuminated visual signals.

a. Illuminated visual signals (indicators, readouts, controls, and push-button switches) requiring readability in direct reflected specular sunlight shall have contrast requirements C_L not less than 0.4 and C_{UL} equal to 0.0 ± 0.1 as defined in 4.6.14.2.1 under a 10,000 footcandle (fc) illumination level at rated drive conditions. Inspection shall be in accordance with 4.6.14.1.

b. Illuminated visual signals not requiring readability in direct reflected specular sunlight shall have contrast of not less than 1.0 as defined in 4.6.14.1 at rated drive conditions. Inspection shall be in accordance with 4.6.14.1.

3.6.1.2 Monochrome electronic and electro-optical displays. Monochrome electronic and electro-optical displays to be used in direct sunlight shall be readable in a combined environment consisting of 10,000 fc diffuse illuminance and the specular

reflection of a 2000 foot-Lamberts (fL) glare source at rated drive conditions. These displays shall meet the minimum contrast and difference luminance requirements specified herein. Inspection shall be in accordance with 4.6.14.2.

3.6.1.2.1 Minimum contrast requirements. Displays shall meet the high ambient daylight contrast requirements of table II. Distinct contrast levels are required for each of the following information categories: (1) numeric information only, (2) alphanumeric information only, (3) graphic information (including alphanumerics as part of its imagery) only and (4) video information. Inspection shall be in accordance with 4.6.14.2.1.

3.6.1.2.2 Compensation multipliers. In the event the spatial characteristics of the imagery do not satisfy the image characteristic constraints stipulated in table II, the contrast requirements in the table shall be modified prior to use using the contrast compensation multipliers of table II.

3.6.1.2.3 Minimum difference luminance. Displays shall produce the minimum difference luminance output (ΔL_{21} and ΔL_{23}) of not less than 100 fL for numeric, alphanumeric and graphic information image elements and not less than 160 fL for video information image elements. Inspection shall be in accordance with 4.6.14.2.2.

3.6.2 Night operations. During night operations, the lighting system shall provide the aircrewmembers with a capability to rapidly and accurately obtain required crewstation information with unaided eye vision. The lighting system shall not have an adverse effect on external unaided night vision or on the aircrew's capability to obtain required information external to the aircraft while employing NVIS.

3.6.3 Environmental operating requirements. The lighting system or component shall meet the environmental operating requirements of the individual equipment specifications and shall be tested in accordance with 4.6.7.

3.6.4 Electromagnetic interference (EMI). Electromagnetic interference requirements shall be in accordance with MIL-STD-461 as specified in the individual equipment specification. Inspection shall be in accordance with 4.6.8.

3.6.5 Electromagnetic compatibility (EMC). The lighting system shall not degrade the capability of the aircraft to meet the EMC requirements as specified in the individual equipment specification. Inspection shall be in accordance with 4.6.9.

3.6.6 Luminance and illuminance. Unless otherwise specified, the levels of luminance or illuminance shall be as required in the applicable documents cited herein for each component, system or subsystem. The levels of luminance for those areas not covered in the applicable documents shall be in accordance with table I. Inspection shall be in accordance with 4.6.10.

TABLE II. High ambient daylight contrast requirements.

Types of information to be displayed	Required contrast (C_L and C_I)	Contrast compensations for other character heights (h) and stroke widths (SW)
Numeric only	≥1.5 for h = 5.0 mm and 0.12h ≤ SW ≤0.2h	Multiply required contrast by 5.0/h for 2.5 ≤h ≤ 7.5 mm and by 0.12h/SW for 0.01h ≤SW ≤ 0.12h
Alphanumerics	≥2.0 for h = 5.0 mm and 0.12h ≤ SW ≤0.2h	
Graphics and alphanumerics	≥3.0	
Video a. Worst case ambient condition: b. Otherwise:	 ≥4.66, to make at least six square root of 2 gray scale ratio shades visible (counting "off" as one) ≥10.3, to make at least eight square root of 2 gray scale ratio shades visible under other than worst case ambient conditions	

NOTES:

1. Character height criteria above assumes a viewing distance of less than 30 inches. No character height shall be less than 0.1 inch.
2. C_{UL} shall be ≤ 0.25 for all displays, and ≤ 0.1 for any display where unlighted elements could provide false information, rather than a meaningless array of dots or segments.
3. Definitions:

C_L = the ON/BACKGROUND contrast of a lighted (or activated) display image element

C_I = the ON/OFF contrast of a display image element

C_{UL} = the OFF/BACKGROUND contrast of an unlighted (or deactivated) display image element

h = character height
SW = character stroke width

3.6.7 Chromaticity. When inspected in accordance with 4.6.11, the color of illuminated information (alphanumeric and symbolic) on instruments, controls, control panels and on illuminated areas in designated crew station and compartment areas shall be as specified herein for that component. These lighting colors and limits are shown on the chromaticity diagrams on figure 2 and are designated as "NVIS GREEN A", "NVIS GREEN B", "NVIS YELLOW" and "NVIS RED". Conformance to these colors and color limits is determined by the following formula:

$$(u' - u'_1)^2 + (v' - v'_1)^2 \leq (r)^2 \qquad \text{(Formula 1)}$$

Where:

u' and v' = 1976 UCS chromaticity coordinates of the test article.

u'_1 and v'_1 = 1976 UCS chromaticity coordinates of the centerpoint of the specified color area

r = radius of the allowable circular area on the 1976 UCS chromaticity diagram for the specified color

3.6.7.1 Primary lighting chromaticity. The chromaticity of the primary lighting system for instruments, displays, consoles, and checklist and radio control plates shall be as specified in table III. At the luminance level specified in table III, the u' and v' chromaticity coordinate values shall be within the area bounded by a circle as shown on figure 2. Inspection shall be in accordance with 4.6.11.1.

3.6.7.2 Secondary lighting subsystem chromaticity. The secondary lighting subsystem shall illuminate the instruments, displays, consoles, and checklist and radio control plates with a lighting color as specified in table III. Lighting components shall produce u' and v' chromaticity coordinates within the area bounded by a circle as shown on figure 2 when energized to produce the luminance level specified in table III measured off a reflectance standard (see appendix A) illuminated and inspected in accordance with 4.6.11.2 and 4.6.11.9 (when applicable).

3.6.7.3 Illuminated control chromaticity. Control lighting color shall be as specified in table III. At the luminance level specified in table III the u' and v' chromaticity coordinate values shall be within the area bounded by a circle as shown on figure 2. Inspection shall be in accordance with 4.6.11.3.

3.6.7.4 Compartment lighting chromaticity. Compartment lighting color shall be as specified in table III. Lighting components shall produce u' and v' chromaticity coordinates within the area bounded by a circle as shown on figure 2 when energized to produce the luminance level specified in table III measured off a reflectance standard surface (see appendix A) illuminated in accordance with 4.6.11.4 and 4.6.11.9 (when applicable) and inspected in accordance with 4.6.11.4.

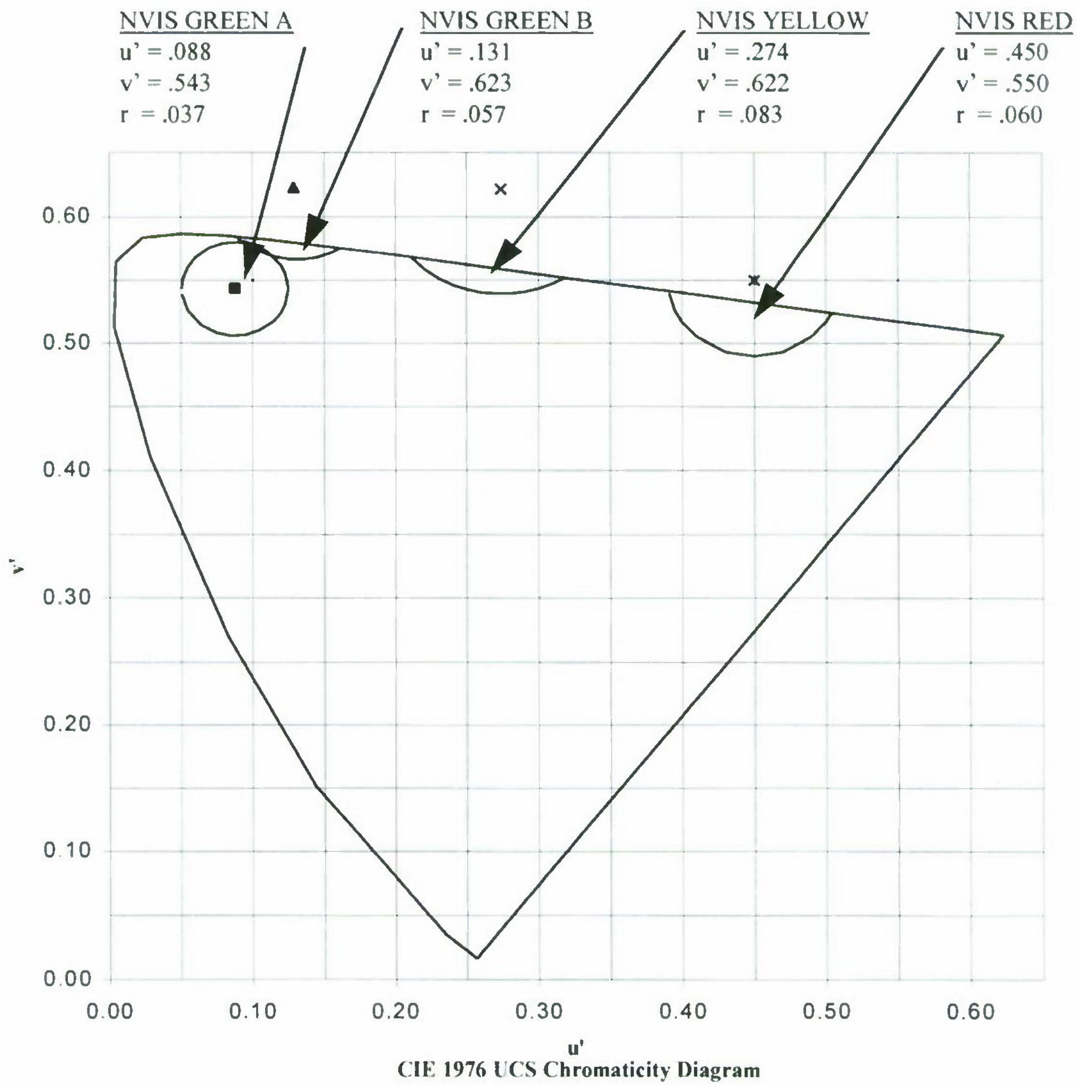


FIGURE 2. NVIS lighting color limits.

3.6.7.5 Utility, work and inspection light chromaticity. Utility, work and inspection lighting color shall be as specified in table III. Lighting components shall produce u' and v' chromaticity coordinates within the area bounded by a circle as shown on figure 2 when energized to produce the luminance level specified in table III measured off a reflectance standard surface (see appendix A) illuminated in accordance with 4.6.11.2 and 4.6.11.9 (when applicable). Inspection shall be in accordance with 4.6.11.5.

3.6.7.6 Caution and advisory lights chromaticity. Caution and advisory lighting color shall be as specified in table III. At the luminance level specified in table III the u' and v' chromaticity coordinate values shall be within the area bounded by a circle as shown on figure 2. Inspection shall be in accordance with 4.6.11.6.

TABLE III. Chromaticity requirements.

Lighting component(s)	Paragraph	TYPE 1										TYPE II									
		Class A					Class B					Class A					Class B				
		u'_1	v'_1	r	fL	NVIS Color	u'_1	v'_1	r	fL	NVIS Color	u'_1	v'_1	r	fL	NVIS Color	u'_1	v'_1	r	fL	NVIS Color
Primary	3.6.71	.088	.543	.037	0.1	Green A	Same as Class A					.088	.543	.037	0.1	Green A	Same as Class A				
Secondary	3.6.7.2	.088	.543	.037	0.1	Green A						.088	.543	.037	0.1	Green A					
Illuminated Controls	3.6.7.3	.088	.543	.037	0.1	Green A						.088	.543	.037	0.1	Green A					
Compartment lighting	3.6.7.4	.088	.543	.037	0.1	Green A						.088	.543	.037	0.1	Green A					
Utility, work, and inspection	3.6.7.5	.088	.543	.037	0.1	Green A						.088	.543	.037	0.1	Green A					
Caution and advisory signals	3.6.7.6	.088	.543	.037	0.1	Green A						.088	.543	.037	0.1	Green A					
Jump lights	3.6.7.7	.088 .274	.543 .622	.037 .083	5.0 15.0	Green A Yellow						.088 .274	.543 .622	.037 .083	5.0 15.0	Green A Yellow					
Special lighting components where increased display emphasis by highly saturared (mono-chromatic) color is necessary, or adequate display light readability cannot be achieved with "GREEN A"	All of the above	.131	.623	.057	0.1	Green B						.131	.623	.057	0.1	Green B					
Warning signal	3.6.7.8.1	.274	.622	.083	15.0	Yellow	.27	.622	.083	15.0	Yellow	.274	.622	.083	15.0	Yellow	.274	.622	.083	15.0	Yellow
		NOT APPLICABLE					.450	.550	.060	15.0	Red	NOT APPLICABLE					.450	.550	.060	15.0	Red
Master Caution signal	3.10.8.8.2	.274	.622	.083	15.0	Yellow	Same as Class A					.274	.622	.083	15.0	Yellow	Same as Class A				

Where:

u'_1 and v'_1 = 1976 UCS chromaticity coordinates of the center point of the specified color area.

r = radius of the allowable circular area on the 1976 UCS chromaticity diagram for the specified color.

fL = footlamberts

TABLE IV. NVIS radiance requirements.

Lighting components		Paragraph	TYPE 1						TYPE II					
			Class A			Class B			Class A			Class B		
			Not Less than (NR_A)	Not Greater than: (NR_A)	fL	Not less Than: (NR_B)	Not Greater Than: (NR_B)	fL	Not Less Than : (NR_A	Not Greater Than: (NR_A)	fL	Not Less Than: (NR_B)	Not Greater Than: (NR_B)	fL
Primary		3.6.8.1	---	1.7x10^{-10}	0.1	1/ Same as Class A			---	1.7x10^{-10}	0.1	1/ Same as Class A		
Secondary		3.6.8.2	---	1.7x10^{-10}	0.1				---	1.7x10^{-10}	0.1			
Illuminated Controls		3.6.8.3	---	1.7x10^{-10}	0.1				---	1.7x10^{-10}	0.1			
Compartment		3.6.8.4	---	1.7x10^{-10}	0.1				---	1.7x10^{-10}	0.1			
Utility, work and inspection lights		3.6.8.5	---	1.7x10^{-10}	0.1				---	1.7-10^{-10}	0.1			
Caution and advisory lights		3.6.8.6	---	1.7x10^{-10}	0.1				---	1.7-10^{-10}	0.1			
Jump lights		3.6.8.7	1.7x10^{-8}	5.0x10^{-8}	5.00	1.6x10-8	4.7x10^{-8}	5.0	---	5.0x10^{-8}	5.0	---	4.7x10^{-8}	5.0
Warning signal		3.6.8.8	5.0x10^{-8}	1.5x10^{-7}	15.0	4.7x10-8	1.4x10^{-7}	15.0	---	1.5x10^{-7}	15.0	---	1.4x10^{-7}	15.0
Master Caution Signal		3.6.8.8	5.0x10^{-8}	1.5x10^{-7}	15.0	4.7x10-8	1.4x10^{-7}	15.0	---	1.5x10^{-7}	15.0	---	1.4x10^{-7}	15.0
Emergency Exit Lighting			5.0x10^{-8}	1.5x10^{-7}	15.0	4.7x10-8	1.4x10^{-7}	15.0	---	1.5x10^{-7}	15.0	---	1.4x10^{-7}	15.0
Electronic and electro-optical displays (Monochromatic)			---	1.7x10^{-10}	0.5	---	1.6x10^{-10}	0.5	---	1.7x10^{-10}	0.5	--	1.6x10^{-10}	10.5
Electronic and electro-optical displays (multi-color	White		---	2.3x10^{-9}	0.5	---	2.2x10^{-9}	0.5	---	2.3x10^{-9}	0.5	---	2.2x10^{-9}	0.5
	MAX		---	1.2x10^{-8}	0.5	---	1.1x10^{-8}	0.5						
HUD systems		3.6.8.10	1.7x10-9	5.1x10-9	5.0	1.6x10-0	4.7x10-9	0.5	---	1.7x10-9	5.0	---	1.6x10-9	5.0

Where:

NOTE 1. For these lighting components, Class B equipment shall meet all Class A requirements of this specification. The relative NVIS response data for Class A equipment, $G_A(\lambda)$ (Table VI), shall be substituted for $G_B(\lambda)$ to calculate NVIS radiance.

NR_A = NVIS radiance requirements for Class A equipment.
NR_B = NVIS radiance requirements for Class B equipment.
fL = footlamberts

3.6.7.7 Jump light chromaticity. The color of jump lights shall be as specified in table III. At the luminance level specified in table III the u' and v' chromaticity coordinate values shall be within the area bounded by a circle as shown on figure 2. Inspection shall be in accordance with 4.6.11.7.

3.6.7.8 Warning and master caution signal chromaticity.

3.6.7.8.1 Warning signal chromaticity. Warning signal lighting color shall be either "NVIS yellow" or "NVIS Red" in accordance with table III as specified by the acquiring activity (see 6.2). At the luminance level specified in table III the u' and v' chromaticity coordinate values shall be within the area bounded by the spectrum locus and a circle, as shown on figure 2. Inspection shall be in accordance with. 4.6.11.8.

3.6.7.8.2 Master caution signal chromaticity. Unless otherwise specified by the acquiring activity (see 6.2), the lighting color for the master caution signal shall be as specified in table III. At the luminance level specified in table III the u' and v' chromaticity coordinate values shall be within the area bounded by the spectrum locus and a circle, as shown on figure 2. Inspection shall be in accordance with 4.6.11.8.

3.6.8 Spectral radiance limits. All interior lighting in aircraft where crew members must utilize NVIS to perform their tasks shall be designed to limit spectral radiance as specified in table IV and herein. Inspection shall be in accordance with 4.6.12.

3.6.8.1 Primary lighting radiance. The NVIS radiance (see 6.3.8) of primary lighting shall be as specified in table IV at the luminance levels specified. These components shall include displays and instruments, display consoles, and checklist and radio control plates. Inspection shall be in accordance with 4.6.12.1.

3.6.8.2 Secondary lighting subsystem radiance. The NVIS radiance of the secondary lighting subsystem shall be such that the NVIS radiance shall be as specified in table IV when energized to produce the luminance level specified in table IV measured off a reflectance standard surface (see appendix A) illuminated in accordance with 4.6.12.2 and 4.6.12.11 (when applicable). Illuminated components shall include displays and instruments, consoles, and checklist and radio control plates. Inspection shall be in accordance with 4.6.12.2 and 4.6.12.11 (when applicable).

3.6.8.3 Illuminated control radiance. The NVIS radiance of illuminated controls shall be such that the NVIS radiance shall be as specified in table IV at the luminance level specified. Inspection shall be in accordance with 4.6.12.3.

3.6.8.4 Compartment light radiance. The NVIS radiance of compartment lights shall be such that the NVIS radiance shall be as specified in table IV when energized to produce the luminance level specified in table IV measured off a reflectance standard surface

(see appendix A) illuminated in accordance with 4.6.12.4 and 4.6.12.11 (when applicable). Inspection shall be in accordance with 4.6.12.4.
3.6.8.5 Utility, work and inspection lighting radiance. The NVIS radiance of utility, work and inspection lights shall be such that the NVIS radiance shall be as specified in table IV when energized to produce the luminance level specified in table IV measured off a reflectance standard surface (see appendix A) illuminated in accordance with 4.6.12.2 and 4.6.12.11 (when applicable). Inspection shall be in accordance with 4.6.12.5.

3.6.8.6 Caution and advisory light radiance. The NVIS radiance of caution and advisory lights shall be such that the NVIS radiance shall be as specified in table IV at the luminance level specified. Inspection shall be in accordance with 4.6.12.6

3.6.8.7 Jump light radiance. The NVIS radiance of jump lights shall be such that the NVIS radiance shall be as specified in table IV at the luminance level specified. Inspection shall be in accordance with 4.6.12.7.

3.6.8.8 Warning and master caution signal and emergency exit lighting radiance. The NVIS radiance of warning and master caution signals and emergency exit lighting shall be as specified in table IV and at the luminance level specified. If these signals have supplementary auditory signals the NVIS radiance may be less than that specified in table IV. Inspection shall be in accordance with 4.6.12.8.

3.6.8.9 Electronic and electro-optical display radiance.

3.6.8.9.1 Monochromatic display radiance. Monochromatic electronic and electro-optical displays except head up display (HUD) systems (see 3.6.8.10) that are required to display shades of gray imagery shall have an NVIS radiance output such that the NVIS radiance shall be as specified in table IV at the luminance level specified. Other electronic displays (having no gray shade capabilities) that are required to display numerics, alphabets, graphics (or a combination thereof) shall also meet the table IV radiance requirement, but at a 0.1 fL luminance level. Inspection shall be in accordance with 4.6.12.9.

3.6.8.9.2 Multi-color display radiance. The spectral radiance output of any color generated by multi-color electronic and electro-optical displays shall be such that the NVIS radiance is not greater than the "Maximum" NR specified for multicolor displays in table IV at the specified luminance level. In addition, the closest producible color to the 1976 UCS chromaticity point u' = .1704, v' = .4042 shall have an NVIS radiance not greater than the "White" specified in table IV at the luminance level specified. Inspection shall be in accordance with 4.6.12.9.

3.6.8.10 HUD system radiance. For HUD systems the NVIS radiance shall be as specified in table IV at the luminance level specified. Inspection shall be in accordance with 4.6.12.10.

3.6.9 Light leaks. In addition to the requirements of the individual equipment specification, lighting components shall not exhibit light leakage (see 6.3.10). Inspection shall be in accordance with 4.6.13.

3.6.10 Luminance uniformity. At any given luminance level, lighting components within a lighting subsystem shall provide luminance such that the average luminance ratio between lighted components shall be not greater than 2 to 1. Inspection shall be in accordance with 4.6.3.

3.6.11 Crewstation reflections. When inspected in accordance with 4.6.4, crewstation reflections shall be as stated herein. Reflections from the canopy and windshields and side windows shall be minimized. Reflections which affect the outside vision of the aviator wearing NVIS shall not be permitted. Specular reflections resulting from aircraft lighting sources shall not occur within the area subtended by a solid angle of one steradian centered at the pilot's design eye position and along the pilot's horizontal vision line. The pilot's design eye position and horizontal vision line are defined in MIL-STD-1776.

3.7 Reliability and maintainability. Reliability and maintainability requirements shall be in accordance with the individual equipment specification.

3.7.1 Luminance balance. Each primary instrument and control panel lighting component shall permit the establishment and maintenance of balanced instrument panel lighting.

4. VERIFICATION

4.1 Classification of inspections. The inspection requirements specified herein are classified as follows:

a. Mockup inspection (see 4.2).

b. First article inspection (see 4.3).

c. Conformance inspection (see 4.4).

4.2 Mockup inspection. When specified by the acquiring activity (see 6.2), a mockup inspection shall be conducted (see 3.3). The mockup inspection shall consist of all of the examinations and tests specified in table V, not necessarily in the order listed.

4.3 First article inspection. The first article inspection shall consist of the examinations and tests specified in the individual equipment specification in addition to those specified in table VI, not necessarily in the order listed.

4.3.1 First article samples. Unless otherwise specified, as soon as practicable after award of the contract or order, the contractor shall submit first article samples as required by the contract or order (see 6.2). The samples shall be representative of the construction, workmanship and materials to be used during production. When a contractor is in continuous production of these systems or components from contract to contract, submission of further first article samples may be waived at the discretion of the acquiring activity (see 6.2). Approval of the first article samples or the waiving of first article inspection does not preclude the requirement of submitting to the quality conformance inspection. The first article inspection samples shall be furnished to the first article inspection laboratory as directed by the contracting officer. The samples shall be plainly marked with the following information:

> Samples submitted by (name of vendor) (date) for first article inspection in accordance with the requirements of this document, Type ( ), Class ( ) under Contract No. ( ).

4.4 Conformance inspection. Conformance inspection shall consist of the examinations and tests as specified in the individual equipment specification in addition to those specified in table VII. The sampling and inspection levels shall be as specified in the individual equipment specification.

4.4.1 Conformance sampling. Samples to be subjected to conformance inspection shall be made essentially under the same conditions and from the same materials.

TABLE V. Mockup inspection.

Inspection	Paragraph	
	Requirement	Inspection method
Lighting system unaided eye	3.3	4.6.1
Lighting system NVIS compatible	3.3	4.6.2
Luminance uniformity	3.6.10	4.6.3
Crewstation reflections	3.6.11	4.6.4
Visual examination	---	4.6.5
Operation	---	4.6.6
Light leak inspection	3.6.9	4.6.13
Daylight legibility and readability	3.6.1	4.6.14

TABLE VI. First article inspection.

Inspection	Paragraph	
	Requirement	Inspection method
Visual examination	---	4.6.5
Operation	---	4.6.6
Environmental operating tests	3.6.3	4.6.7
Electromagnetic interference	3.6.4	4.6.8
Electromagnetic compatibility	3.6.5	4.6.9
Luminance and illuminance	3.6.6	4.6.10
Chromaticity	3.6.7	4.6.11
Spectral radiance	3.6.8	4.6.12
Light leak inspection	3.6.9	4.6.13
Daylight legibility and readability	3.6.1	4.6.14

TABLE VII. Conformance inspection.

Inspection	Paragraph	
	Requirement	Inspection method
Visual examination	---	4.6.5
Operation	---	4.6.6
Luminance and illuminance	3.6.6	4.6.10
Chromaticity	3.6.7	4.6.11
Spectral radiance	3.6.8	4.6.12
Light leak inspection	3.6.9	4.6.13
Daylight legibility and readability	3.6.1	4.6.14

4.5 Inspection conditions.

4.5.1 Atmospheric conditions. Unless otherwise specified in the individual equipment specification, first article and conformance inspections herein shall be performed at atmospheric pressure of 28 to 32 inches Hg at a temperature of 21° ± 3° C, and a relative humidity of 80% or less.

4.5.2 Order of inspection. All inspections shall be performed after the environmental inspections required by the individual equipment specification.

4.5.3 Lighting conditions. Luminance, chromaticity and radiance measurements shall be made in a dark room where the ambient spectral radiant energy over the spectral range of 380 through 930 manometers is either unmeasurable (equivalent to measurement instrument system noise) or no greater than 1% of the value of radiant energy from the test sample being measured.

4.5.3.1 Test set up verification. With all the equipment positioned in the darkroom as they would be for test measurements, focus the spectroradiometer on a reflectance standard meeting the requirements of appendix A located in place of the test sample and, with the room in a darkened condition, measure the ambient radiant energy incident on the reflectance standard. The data obtained shall be kept on file and shall be compared with data subsequently developed from all test samples to verify compliance with the requirements of 4.5.3. This verification procedure shall be repeated when the darkroom ambient spectral radiant energy levels become suspect or at six month intervals, whichever occurs first.

4.5.4 Test set up. Stray light from the test lighting component shall be controlled so that it is not reflected, refracted, or scattered into the measuring equipment.

4.6 Inspection methods and procedures.

4.6.1 Lighting system unaided eye inspection. During the mockup inspection of 3.3, each lighting subsystem (primary instrument panel, secondary instrument panel, primary console, secondary console, warning, caution and advisory signals, utility, and compartment) shall first be subjected to an unaided eye inspection at the lighting levels specified in 3.3. This inspection shall then be repeated at the NVIS compatible lighting levels specified in table IV. Nonconformance to 3.3 shall constitute failure of this test.

4.6.2 Lighting system NVIS compatible examination. During the mockup inspection of 3.3, each lighting subsystem, (primary instrument panel, secondary instrument panel, primary console, secondary console, warning, caution and advisory signal, utility, and compartment light) shall be set to the NVIS compatible lighting level cited in table IV and examined while utilizing NVIS to verify general conformance to this document, as well as to identify any source of light leakage from the various lighting components.

The NVIS used during the evaluation shall be representative of the system planned for use in the aircraft. Either of two resolution targets may be used for the assessment; procedures applicable to the chosen target shall be used. In either case, the resolution target shall be irradiated so that NVIS radiance of white portions of the resolution target equals $1.7 \times 10^{-10} NR_A$ (for class A NVIS) or $1.6 \times 10^{-10} NR_B$ (for class B NVIS). Contrast of the target shall be calculated using the following formula:

$$C_m = \frac{L_s - L_b}{L_s + L_b}$$

where:

C_m = contrast modulation

L_s = luminance of target white space

L_b = luminance of target dark bar

Contrast modulation shall be as specified for the type of target used. Care shall be taken to locate the resolution target so that aircraft lighting subsystems, when energized, do not illuminate the target. The position of the target shall be subject to approval of the acquiring activity. The NVIS shall be focused on the target for best resolution performance. NVIS resolution performance shall be assessed with all lighting subsystems off.

4.6.2.1 Resolution assessment using a USAF 1951 medium contrast target. A USAF 1951 medium contrast resolution resolving power target (USAF Tr-bar Chart) with a contrast modulation (C_m) of approximately 70% shall be used. The chart shall be set up outside the mockup at a distance such that the test subject, while seated in the aircraft in the appropriate operational position and wearing NVIS, is just capable of resolving an element in a target group midway between the largest and smallest groups when the chart is irradiated as specified. Nonconformance to 3.3 shall constitute failure of this test.

4.6.2.2 Resolution assessment using a 50% contrast square wave grating NVG resolution chart. A square wave grating pattern NVG resolution chart having a contrast modulation C_m of approximately 50% shall be used. The NVG resolution chart shall contain horizontally and vertically oriented square wave gratings patterns which determine Snellen acuities of 20/20, 20/25, 20/30, 20/35, 20/40, 20/45, 20/50, 20/55, 20/60, 20/65, and 20/70 when resolved at a viewing distance of 20 feet. The chart shall be set up outside the mockup at a distance of 20 feet from the test subject and irradiated as specified. Nonconformance to 3.3 shall constitute failure of this test.

4.6.3 Luminance uniformity.

4.6.3.1 Low level. During the mockup inspection, each lighting subsystem shall be energized independently to one half of its rated voltage. A visual inspection shall be made to determine the brightest and dimmest lighting component of that subsystem. Unless visual inspection has been accepted for luminance uniformity by the acquiring activity, a photometer in accordance with appendix A shall be used to measure the luminance of the brightest and dimmest lighting component. Nonconformance to 3.6.10 shall constitute failure of this test.

4.6.3.2 High level. Each lighting subsystem shall then be energized independently to maximum brightness. A visual inspection shall be made to determine the brightest and dimmest component of that subsystem. A photometer in accordance with appendix A shall be used to measure the luminance of the brightest and dimmest lighting component. Nonconformance to 3.6.10 shall constitute failure of this test.

4.6.4 Crewstation reflections. Examination for specular reflections shall be performed during the mockup inspection (see 4.6.2). Nonconformance to 3.6.11 shall constitute failure of this test.

4.6.5 Visual examination. Each lighting system, subsystem, or component shall be examined visually to determine conformance with this document. Any evidence of foreign matter, cracks, scratches, bubbles, delamination, warps or stray light shall be considered cause for rejection.

4.6.6 Operation. Each lighting system, subsystem, or component to be inspected shall be energized as specified in 3.5.3 to determine that it operates in accordance with this document.

4.6.7 Environmental operating tests. Each lighting system, subsystem, or component shall be tested in accordance with the environmental operating test criteria of the individual equipment specification.

4.6.8 Electromagnetic interference (EMI) tests. EMI tests shall be performed in accordance with MIL-STD-462. Nonconformance to 3.6.4 shall constitute failure of this test.

4.6.9 Electromagnetic compatibility (EMC) tests. EMC test shall be performed in accordance with the individual equipment specification. Nonconformance to 3.6.5 shall constitute failure of this test.

4.6.10 Luminance and illuminance measurements. Unless otherwise specified herein, luminance and illuminance measurements shall be performed in accordance with the

individual equipment specification for the applicable lighting component. Luminance or illuminance measurements shall be performed by using either a spectroradiometer or photometer meeting the requirements of appendix A. When a spectroradiometer, meeting the requirements of appendix A is used to measure luminance or illuminance, the luminance or illuminance shall be calculated using the following standard formulas. Nonconformance to 3.6.6 shall constitute failure of this test.

$$L = 929\pi K(\lambda)_{max} \int_{380}^{780} K(\lambda)N(\lambda)d\lambda \qquad \text{(Formula 2)}$$

$$E_v = 929 K(\lambda)_{max} \int_{380}^{780} K(\lambda)E_e(\lambda)d\lambda \qquad \text{(Formula 3)}$$

Where:

L	=	luminance (footlamberts) or
E_v	=	illuminance (footcandles)
$K(\lambda)$	=	normalized visual efficiency curve for 1931 standard observer
$K(\lambda)_{max}$	=	683 lm/W
$N(\lambda)$	=	spectral radiance of lighting component (W/cm^2 sr nm)
$E_e(\lambda)$	=	flux density incident (W/cm^2)
$d\lambda$	=	5 nm

4.6.11 Chromaticity measurements.

4.6.11.1 Primary lighting chromaticity measurements. Chromaticity measurements shall be made in a dark room meeting the requirements of 4.5.3. Depending on the type of lighting component being evaluated, the drive condition shall be applied to the lighting components necessary to achieve the luminance level of table VIII for the applicable component. The luminance shall be measured using either a spectroradiometer or photometer meeting the requirements specified in appendix A.

With the specified luminance achieved, the spectral output of the lighting component shall be measured with a spectroradiometer which meets the requirements of appendix A. Each spectral measurement shall be made using the actual aircraft lighting source, filter, and fixture. The spectroradiometer shall be placed a distance from the device being tested so that several numbers, letters, or indicia are included within the spectroradiometer test field. The x and y and the u' and v' 1976 UCS chromaticity coordinate points shall then be calculated using the following formulas. Nonconformance to 3.6.7.1 shall constitute failure of this test.

$$N(\lambda) = I(\lambda)/R(\lambda) \qquad \text{(Formula 4)}$$

$$X = \int_{380}^{780} \bar{x}\ N(\lambda)\ d\lambda \qquad \text{(Formula 5)}$$

$$Y = \int_{380}^{780} \bar{y}\ N(\lambda)\ d\lambda \qquad \text{(Formula 6)}$$

$$Z = \int_{380}^{780} \bar{z}\ N(\lambda)\ d\lambda \qquad \text{(Formula 7)}$$

$$x = \frac{X}{X+Y+Z} \qquad \text{(Formula 8)}$$

$$y = \frac{Y}{X+Y+Z} \qquad \text{(Formula 9)}$$

$$u' = \frac{4x}{-2x+12y+3} \qquad \text{(Formula 10)}$$

$$v' = \frac{9y}{-2x+12y+3} \qquad \text{(Formula 11)}$$

Where:

$N(\lambda)$	=	spectral radiance of the lighting component (W/cm^2 sr nm or normalized)
$I(\lambda)$	=	detector current (amperes)
$R(\lambda)$	=	spectroradiometer spectral sensitivity (amperes cm^2 sr nm/W)
$d\lambda$	=	5nm
$\bar{x}$	=	1931 C.I.E. relative spectral response of the eye (color matching function)
$\bar{y}$	=	1931 C.I.E. relative spectral response of the eye (color matching function)
$\bar{z}$	=	1931 C.I.E. relative spectral response of the eye (color matching function)
X	=	C.I.E. tristimulus value
Y	=	C.I.E. tristimulus value
Z	=	C.I.E. tristimulus value
u'	=	1976 UCS chromaticity coordinate transformation of CIE x
v'	=	1976 UCS chromaticity coordinate transformation of CIE y
x	=	1931 C.I.E. chromaticity coordinate
y	=	1931 C.I.E. chromaticity coordinate

4.6.11.2 Secondary lighting chromaticity measurements. For chromaticity measurements the appropriate drive condition shall be applied to the light being tested (test light) to illuminate a reflectance standard meeting the requirements of appendix A, to a luminance level of 0.1 fL at a distance of 12 inches. The test light shall be oriented

perpendicular to the reflectance standard. The spectroradiometer shall be set up such that the reflectance standard is at a 45° angle with the line of sight of the spectroradiometer. The spectral radiance of the reflectance standard shall be measured using an aperture that is as large as possible within the projected area of the reflectance standard. The corrected spectral radiance shall then be calculated using the following formula:

$$N(\lambda) = \frac{M(\lambda)}{r(\lambda)} \qquad \text{(Formula 12)}$$

Where:

$N(\lambda)$ = corrected spectral radiance (W/cm^2 sr nm)

$M(\lambda)$ = measured spectral radiance of the reflectance standard (W/cm^2 sr nm)

$r(\lambda)$ = reflectance of the reflectance standard

The chromaticity of the test light shall be calculated using the corrected spectral radiance and the formulas given in 4.6.11.1 Nonconformance to 3.6.7.2 shall constitute failure.

4.6.11.3 Illuminated control chromaticity measurements. Inspection shall be in accordance with 4.6.11.1. Nonconformance to 3.6.7.3 shall constitute failure.

4.6.11.4 Compartment lighting chromaticity measurements. The chromaticity inspection for compartment lighting shall be the same as for secondary lighting (4.6.11.2) except that the distance between the test light and the reflectance standard shall be adjusted to be equivalent to the distance at which the lighting component will be used when installed in an aircraft. Nonconformance to 3.6.7.4 shall constitute failure.

4.6.11.5 Utility, work and inspection lighting chromaticity measurements. Inspection shall be the same as for secondary lighting (4.6.11.2). Nonconformance to 3.6.7.5 shall constitute failure.

4.6.11.6 Caution and advisory light chromaticity measurements. Inspection shall be in accordance with 4.6.11.1. Nonconformance to 3.6.7.6 shall constitute failure.

4.6.11.7 Jump light chromaticity measurements. Inspection shall be in accordance with 4.6.11.1. Nonconformance to 3.6.7.7 shall constitute failure.

4.6.11.8 Signal indicator chromaticity measurements. Inspection shall be in accordance with 4.6.11.1. Nonconformance to 3.6.7.8 shall constitute failure.

4.6.11.9 Floodlighted instrument, console and panel chromaticity measurements. The chromaticity of instruments, consoles and panels intended to be floodlighted shall be in accordance with 4.6.11.2 except that the instrument console or panel shall be floodlighted to the specified luminance levels by the same type of light that will be used when the panel is installed in the aircraft. Nonconformance to 3.6.8 shall constitute failure.

4.6.12 Spectral radiance measurements.

4.6.12.1 Primary lighting spectral radiance measurements. NVIS radiance measurements shall be made in a dark room meeting the requirements of 4.5.3. Power shall be applied to the lighting component in such a manner that the luminance at the rated drive condition or 15.0 fL, whichever is less, is achieved. The luminance shall be measured using a spectroradiometer meeting the requirements specified in appendix A. With the appropriate luminance achieved, a spectroradiometer which meets the requirements of appendix A shall be set up to measure the spectral radiance. The aperture selected for measurement shall provide spectroradiometer sensitivity in accordance with A.3.2. If the size of numerals, lettering or indicia permit, the spectroradiometer shall be set up to measure at least three different areas on the device. If size does not permit spectral radiance measurements of individual numerals, lettering or indicia, the spectral radiance shall be measured by including several numeral(s), lettering, and indicia within the spectroradiometer test field. The NVIS radiance shall be calculated using the appropriate formulas herein. Nonconformance to 3.6.8.1 shall constitute failure of this test. A scaling factor shall be generated using the following formula:

$$S = \frac{L_r}{L_m} \qquad \text{(Formula 13)}$$

Where:

S = scaling factor

L_r = required luminance level for NVIS radiance (see table IV)

L_m = spectrally-averaged luminance calculated by using the same spectroradiance data used in Formulas 14a and 14b.

Tests to verify that the scale factor "S" is valid must be accomplished if there is any doubt that the luminance and radiance of the display or lighting technology being used scale together.

Formula 14a shall be used to calculate the NVIS radiance of Class A equipment.

Formula 14b shall be used to calculate the NVIS radiance of Class B equipment.

$$\text{NVIS radiance (NRA)} = S \int_{450}^{930} G_A(\lambda)N(\lambda)d\lambda \qquad \text{(Formula 14a)}$$

$$\text{NVIS radiance (NRB)} = S \int_{450}^{930} G_B(\lambda)N(\lambda)d\lambda \qquad \text{(Formula 14b)}$$

Where:

$GA(\lambda)$ = relative NVIS response of Class A equipment (see table VIII)

$GB(\lambda)$ = relative NVIS response of Class B equipment (see table IX)

$N(\lambda)$ = spectral radiance of lighting component (W/cm^2 sr nm)

S = scaling factor

$d\lambda$ = 5 nm

4.6.12.2 Secondary lighting radiance measurements. The appropriate drive condition shall be applied to the test light to illuminate the reflectance standard such that the luminance requirement of table IV is met at a distance of 12 inches. The test light shall be oriented perpendicular to the reflectance standard. The spectroradiometer shall be set up such that the reflectance standard is at a 45° angle with the line of sight of the spectroradiometer. The spectral radiance of the reflectance standard shall be measured. The corrected spectral radiance shall then be calculated using Formula 12 and the NVIS radiance shall be calculated using the corrected spectral radiance and the formulas in 4.6.12.1. Nonconformance to 3.6.8.2 shall constitute failure.

4.6.12.3 Illuminated control radiance measurements. Inspection shall be in accordance with 4.6.12.1. Nonconformance to 3.6.8.3 shall constitute failure.

4.6.12.4 Compartment lighting radiance measurements. The NVIS radiance inspection for compartment lighting shall be the same as for secondary lighting (4.6.12.2) except that the distance between the test light and the reflectance standard shall be adjusted to be equivalent to the distance at which the lighting component will be used when installed in an aircraft. Nonconformance to 3.6.8.4 shall constitute failure.

TABLE VIII. Relative spectral response of Class A NVIS ($G_A(\lambda)$).

Wavelength (nm)	Relative Response	Wavelength (nm)	Relative Response
450	1.0000E-04	690	9.3790E-01
455	1.1250E-04	695	9.4480E-01
460	1.2500E-04	700	9.5170E-01
465	1.3750E-04	705	9.5860E-01
470	1.5000E-04	710	9.6550E-01
475	1.6172E-04	715	9.7304E-01
480	1.7500E-04	720	9.7930E-01
485	1.9375E-04	725	9.8020E-01
490	2.1250E-04	730	9.8280E-01
495	2.2266E-04	735	9.8838E-01
500	2.3750E-04	740	9.9310E-01
505	2.7656E-04	745	9.9719E-01
510	3.1250E-04	750	1.0000E+00
515	3.4297E-04	755	1.0000E+00
520	3.7500E-04	760	1.0000E+00
525	4.1875E-04	765	1.0000E+00
530	4.6250E-04	770	1.0000E+00
535	5.0703E-04	775	9.9814E-01
540	5.5000E-04	780	9.9660E-01
545	5.8359E-04	785	9.9543E-01
550	6.2500E-04	790	9.9450E-01
555	7.0000E-04	795	9.9380E-01
560	7.7500E-04	800	9.9310E-01
565	8.5000E-04	805	9.8620E-01
570	9.2500E-04	810	9.7930E-01
575	1.4525E-03	815	9.7283E-01
580	1.9800E-03	820	9.6550E-01
585	4.7175E-03	825	9.5515E-01
590	7.8000E-03	830	9.4480E-01
595	1.1400E-02	835	9.3402E-01
600	1.5000E-02	840	9.2410E-01
605	2.6263E-02	845	9.1720E-01
610	5.2000E-02	850	9.1030E-01
615	8.8388E-02	855	8.6334E-01
620	1.7500E-01	860	8.0000E-01
625	4.3288E-01	865	7.2848E-01

630	6.1380E-01	870	6.5520E-01
635	6.7756E-01	875	5.8016E-01
640	7.4480E-01	880	5.0340E-01
645	8.2458E-01	885	4.2523E-01
650	8.8970E-01	890	3.4480E-01
655	8.9654E-01	895	2.5704E-01
660	9.0340E-01	900	1.7500E-01
665	9.1051E-01	905	1.1009E-01
670	9.1720E-01	910	6.2100E-02
675	9.2241E-01	915	4.3125E-02
680	9.2760E-01	920	2.7600E-02
685	9.3254E-01	925	1.5525E-02
		930	6.9000E-03

TABLE IX. Relative spectral response of Class B NVIS ($G_B(\lambda)$).

Wavelength (nm)	Relative Response	Wavelength (nm)	Relative Response
450	1.0000E-05	690	9.3790E-01
455	1.1250E-05	695	9.4480E-01
460	1.2500E-05	700	9.5170E-01
465	1.3750E-05	705	9.5860E-01
470	1.5000E-05	710	9.6550E-01
475	1.6172E-05	715	9.7304E-01
480	1.7500E-05	720	9.7300E-01
485	1.9375E-05	725	9.8020E-01
490	2.1250E-05	730	9.8280E-01
495	2.2266E-05	735	9.8838E-01
500	2.3750E-05	740	9.9310E-01
505	2.7657E-05	745	9.9719E-01
510	3.1250E-05	750	1.0000E+00
515	3.4297E-05	755	1.0000E+00
520	3.7500E-05	760	1.0000E+00
525	4.1875E-05	765	1.0000E+00
530	4.6250E-05	770	1.0000E+00
535	5.0703E-05	775	9.9814E-01
540	5.5000E-05	780	9.9660E-01
545	5.8359E-05	785	9.5430E-01
550	6.2500E-05	790	9.9450E-01
555	7.0000E-05	795	9.9830E-01
560	7.7500E-05	800	9.9310E-01
565	8.5000E-05	805	9.8620E-01
570	9.2500E-05	810	9.7930E-01
575	9.7688E-05	815	9.7283E-01
580	1.1000E-04	820	9.6550E-01
585	1.2566E-04	825	9.5515E-01
590	1.8200E-04	830	9.4480E-01
595	2.6581E-04	835	9.3402E-01
600	5.2500E-04	840	9.2410E-01
605	1.0183E-03	845	9.1720E-01
610	2.0000E-03	850	9.1030E-01
615	3.4569E-03	855	8.6334E-01
620	6.2500E-03	860	8.0000E-01
625	9.0935E-03	865	7.2848E-01

630	1.8414E-02	870	6.5520E-01
635	4.6447E-02	875	5.8016E-01
640	7.4480E-02	880	5.0340E-01
645	2.0949E-01	885	4.2523E-01
650	4.0037E-01	890	3.4480E-01
655	6.7139E-01	895	2.5704E-01
660	9.0340E-01	900	1.7500E-01
665	9.1073E-01	905	1.1009E-01
670	9.1720E-01	910	6.2100E-02
675	9.2741E-01	915	4.3125E-02
680	9.2760E-01	920	2.7600E-02
685	9.3254E-01	925	1.5525E-02
		930	6.9000E-03

4.6.12.5 Utility, work and inspection lighting radiance measurements. Inspection shall be the same as for secondary lighting (4.6.12.2). Nonconformance to 3.6.8.5 shall constitute failure.

4.6.12.6 Caution and advisory light radiance measurements. Inspection shall be in accordance with 4.6.12.1. Nonconformance to 3.6.8.6 shall constitute failure.

4.6.12.7 Jump light radiance measurements. Inspection shall be in accordance with 4.6.12.1. Nonconformance to 3.6.8.7 shall constitute failure.

4.6.12.8 Signal indicator radiance measurements. Inspection shall be in accordance with 4.6.12.1. Nonconformance to 3.6.8.8 shall constitute failure.

4.6.12.9 Electronic and electro-optical display radiance measurements. Inspection shall be in accordance with 4.6.12.1. The acquiring activity shall specify the number and type of colors or composite colors that shall be measured (see 6.2). The spectroradiometer shall be placed so that as much of the display as reasonably possible is within the spectroradiometer test field. Nonconformance to 3.6.8.9 shall constitute failure.

4.6.12.10 HUD system radiance measurements. Inspection shall be in accordance with 4.6.12.1 and as stated herein. If the display is unable to generate the luminance level specified in table IV, NVIS radiance shall be measured at the display's maximum luminance level and scaled to the specified luminance level. Nonconformance to 3.6.8.10 shall constitute failure.

4.6.12.11 Floodlighted instrument, console and panel radiance measurements. The NVIS radiance inspection of instruments, consoles and panels intended to be floodlighted shall be in accordance with 4.6.12.1 except that the instrument console or panel shall be floodlighted to the specified luminance levels by the same type of light that will be used when the panel is installed in the aircraft. Nonconformance to 3.6.8 shall constitute failure.

4.6.13 Light leak inspection. The lighting component, system, or subsystem shall be illuminated as specified and examined through the NVIS for evidence of light leakage. Nonconformance to 3.6.9 shall constitute failure.

4.6.14 Daylight legibility and readability inspection.

4.6.14.1 Illuminated visual signals.

a. Illuminated visual signals requiring readability in direct reflected specular sunlight shall be tested as shown on figure 3a. A light source of 3,000 to 5,000 Kelvin color temperature shall be directed at an angle of ϕ_1 = 15° $\pm$ 2° to the normal of a diffuse

reflectance standard. The size of the light source shall be limited so that $\theta \leq 20^\circ$. A photometer shall be positioned at an angle of $\phi_2 = 15^\circ \pm 2^\circ$ to the normal of the reflectance standard. The light source shall be adjusted to produce 10,000 foot candles illumination on the reflectance standard as measured by the photometer. The reflectance standard shall then be removed and replaced by the viewing surfaces of the display to be tested. L_1, L_2, and L_3 shall be measured and C_L and C_{UL} shall be calculated, as defined in 4.6.14.2.1. The test shall be repeated with ϕ_1 and $\phi_2 = 30^\circ \pm 2^\circ$. Nonconformance to 3.6.1.1 shall constitute failure.

b. Illuminated visual signals not requiring readability in direct reflected specular sunlight shall be tested as shown on figure 3b. A light source of 3,000 to 5000 Kelvin color temperature shall be located on the normal to the display surface. A photometer shall be positioned at an angle of $\phi_1 = 30^\circ \pm 2^\circ$ from the normal. The light source shall be adjusted to produce 10,000 foot candles illumination on the reflectance standard as measured by the photometer. The reflectance standard shall then be removed and replaced by the viewing surfaces of the display to be tested. L_1 and L_2 shall be measured and C_L shall be calculated, as defined in 4.6.14.2.1. Nonconformance to 3.6.1.1 shall constitute failure.

4.6.14.2 Monochrome electronic and electro-optical display inspection. Inspection shall be as specified herein. Light sources used for legibility and readability testing shall have a color temperature of not less than 3000°K and not greater than 6500 °K.

4.6.14.2.1 Minimum contrast measurements. The following display luminance quantities shall be measured in the ambient lighting conditions specified in 3.6.1.2 using the techniques specified herein.

L_1, the average background luminance of the display surface in areas adjacent to and therefore visually contrasted with activated display image elements.

L_2, the average luminance of activated display image elements.

L_3, the average luminance of deactivated display image elements.

An image element consists of the spatially distinguishable portions of displayed characters, symbols or video image patterns which must as a minimum be visually discriminated to make the display information recognizable to an observer (i.e., it consists of as a minimum one, but more typically several display picture elements). Using these measured luminance values, L_1, L_2, and L_3, three contrasts (C_L, C_l and C_{UL}) shall be calculated employing the following equations (see 6.3.11). Nonconformance to 3.6.1.2 shall constitute failure.

$$C_L = \frac{L_2 - L_1}{L_1} = \frac{\Delta L_{21}}{L_1} \qquad \text{(Formula 15)}$$

Where: C_L = the ON/BACKGROUND contrast of a lighted (or activated) display image element

$$C_I = \frac{L_2 - L_3}{L_3} = \frac{\Delta L_{23}}{L_3} \qquad \text{(Formula 16)}$$

Where: C_I = the ON/OFF contrast of a display image element

$$C_{UL} = \frac{L_3 - L_1}{L_1} = \frac{\Delta L_{31}}{L_1} \qquad \text{(Formula 17)}$$

Where: C_{UL} = the OFF/BACKGROUND contrast of an unlighted (or deactivated) display image element

4.6.14.2.2 Luminance measurements. To measure L_1, L_2 and L_3, with which to calculate contrast (Formulas 15 thru 17), the direct area average measurement technique of 4.6.14.2.2.1 or the indirect area averaged measurement technique of 4.6.14.2.2.2 shall be used. If the image elements are large enough to permit several nonoverlapping measurements to be made within the image element boundaries (for example, for numeric readout segments) luminance readings spaced nominally one sensor aperture diameter apart shall be taken and averaged to establish the image element luminance. The average luminance of display image elements in a minimum of five spatially distributed areas of the display surface shall be determined. Nonconformance to 3.6.1.2.1 through 3.6.1.2.3 shall constitute failure. If it can be demonstrated that the difference luminance terms do not change under high ambient illuminance or that they change in a predictable manner, the luminance terms L_1, L_2 and L_3 used to calculate the difference luminance values may at the option of the test activity be measured in low or medium ambient illuminance test conditions to improve the accuracy of the measurements. The same luminance sensing aperture size shall be used to measure L_2 and L_3. Nonconformance to 3.6.1.2.1 through 3.6.1.2.3 shall constitute failure.

4.6.14.2.2.1 Direct area average measurements. A photometer which measures an area that subtends an angle of 1.8 minute or more of arc at the intended pilot to display viewing distance shall be used to make the luminance measurements.

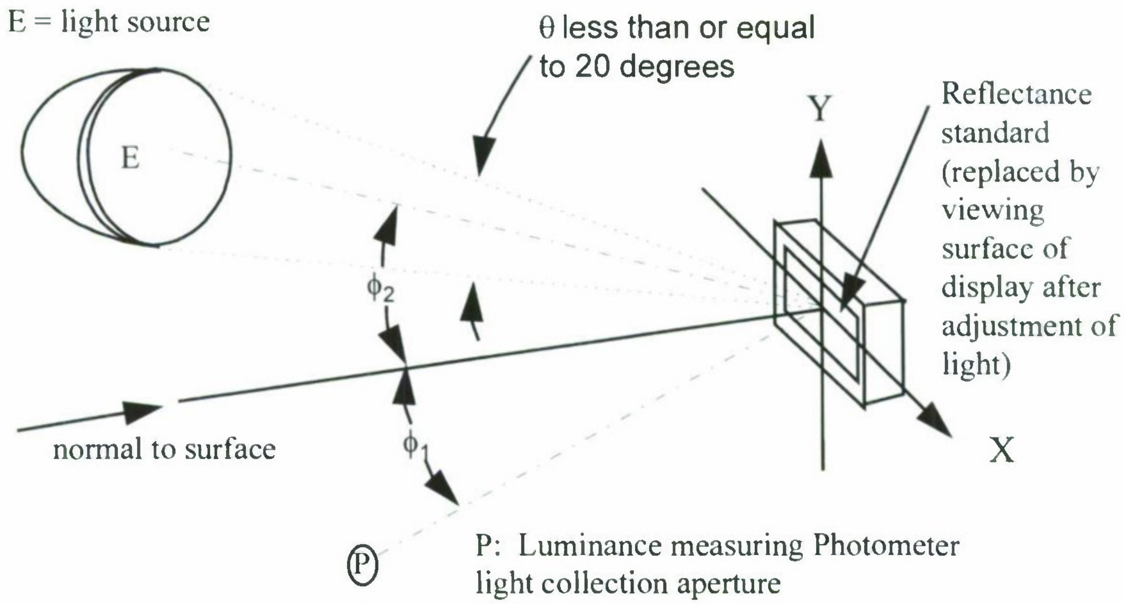


FIGURE 3 a. Direct reflected specular measurement configuration

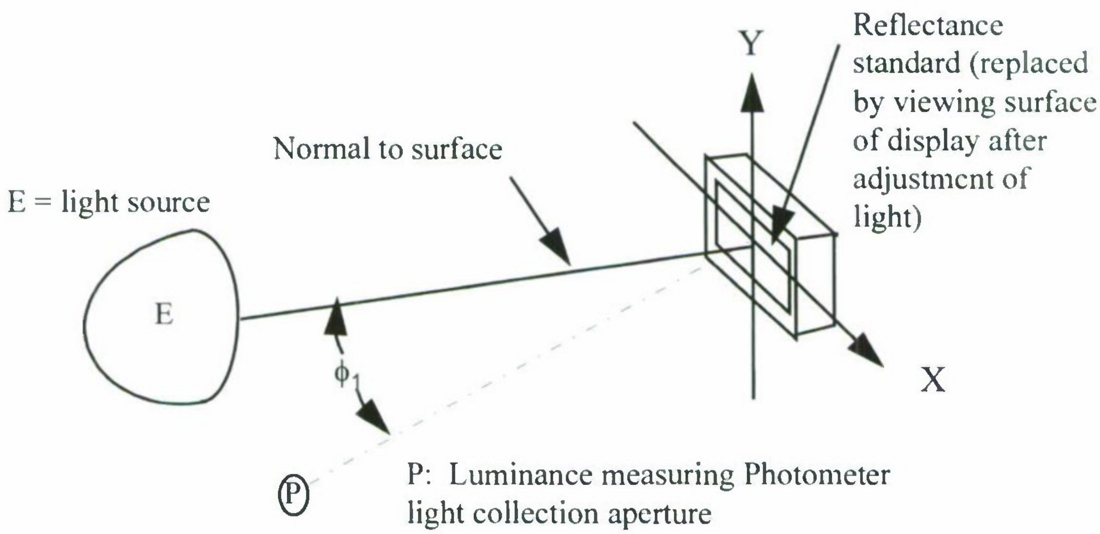


FIGURE 3 b. Non-specular measurement configuration

FIGURE 3. Illuminated visual signals measurement configurations.

4.6.14.2.2.2 <u>Indirect area averaged measurements</u>. If a photometer with a sensing area smaller than that specified in 4.6.14.2.2.1 is used, a sufficient number of luminance readings shall be taken to permit determining the average luminance over the area of the 1.8 minute or more of arc diameter sensing aperture. Within this aperture, both active and inactive areas of the display surface shall be averaged. Positioning of this measurement aperture within the area of an image element to achieve maximum readings is permissible.

4.6.14.2.3 <u>Reflected luminance measurements</u>. The terms L_1, L_2 and L_3 in the contrast equations (Formulas 15 through 17) shall include the combined effects of both specular and the diffuse reflected luminance contributions. The measurements may be made using either a two light source configuration capable of simultaneously inducing both the specular and the diffuse reflected luminance contributions, as illustrated on figure 4, or through separate measurements using one source at a time and summing the specular and diffuse reflected luminance contributions.

4.6.14.2.3.1 <u>Diffuse reflected luminance measurements</u>. The illuminance source E_I on figure 4 shall be positioned on the display's axis perpendicular to the display face. The diffuse reflected luminance shall be measured by the photometer, P, which is oriented at an angle, $\theta_p = 30 \pm 2°$ or the maximum viewing angle at which the display is expected to achieve full performance (unless otherwise specified in the contract) with respect to n. The photometer shall be focused to produce a clear measurement spot at the display surface. With a white diffuse reflecting standard surface (barium sulfate or equivalent) substituted for the display surface, the source, E_I, shall be adjusted to produce 10,000 fL luminace at the reflecting standard surface. The white reflectance standard surface shall then be removed and replaced by the display surface to be measured. The display shall be translated with a combination of X and Y display motions (see figure 4) to measure L_1, L_2 and L_3. A luminance measuring aperture larger than that used to measure L_2 and L_3 may, if desired, be used to measure L_1. If the values of the difference luminances ΔL_{21} and ΔL_{23} must be established under high ambient illuminance (see 4.6.14.2.2), the diffuse reflectance test condition above shall be used. If the option to measure the display difference luminance in lower ambient illumination conditions has been justified in accordance with 4.6.14.2.2, the measurement of L_2 may be omitted in this procedure. Subject to the approval of the acquiring activity, diffuse reflected luminance readings taken normal to the display surface using an integrating sphere, with its internal surface reflected luminance adjusted to 10,000 fL, may be substituted for the spot source procedure just described.

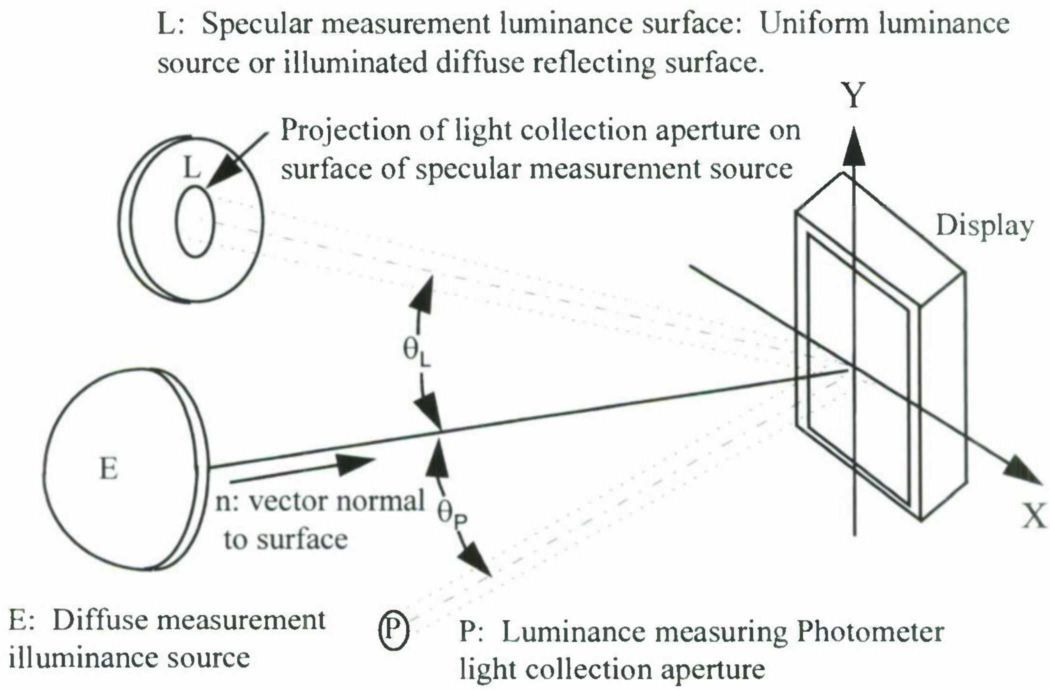


FIGURE 4. Combined specular/diffuse measurement configuration.

4.6.14.2.3.2 Specular reflected luminance measurements. The surface labeled, L, on figure 4 oriented at an angle $\theta_L = \theta_P$ produces a luminance which when mirrored by the display surface can be sensed by the photometer, P, as a defocused image (i.e., the photometer remains focused on the display surface as the viewers' eyes would when using the display). The luminous surface, L, may be a light source, a transilluminated surface or as illustrated on figure 4, a diffuse light reflecting surface illuminated by the light source labeled E. With a mirror substituted for the display surface, the photometer, the light source and the mirror shall or be oriented to achieve an angular relationship such that $\theta_p = \theta_L = 30°$ or the maximum viewing angle at which the display is expected to achieve full performance (unless otherwise specified in the contract) and to simultaneously permit filling an area in the photometer measurement field surrounding the measurement spot that is at least three times the apparent diameter of the spot, or the entire photometer viewing field, whichever is smaller. The luminance of the source,

L, shall then be adjusted to 2,000 fL as measured by the photometer focused at the mirror surface. Replace the mirror surface with the display surface. Measure the luminances specularly reflected by the display surface, or by any intervening display optical filter elements. The display shall then be translated as previously described to permit image background luminance measurements, and off image luminance measurements. The specular test procedure just described should produce some diffuse illumination on the display, but this is normally less than 100 fc and may be ignored relative to the 10,000 fc used in the diffuse test.

5. PACKAGING

This section is not applicable to this document.

6. NOTES

(This section contains information of general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use. The lighting requirements specified herein are intended to cover all of the aircraft interior lighting of equipment areas, crewstations and compartments in which aircrewmembers must perform their duties while wearing NVIS.

6.2 Acquisition requirements. Acquisition documents should specify the following:

a. Title, number and date of this document.

b. Type, class and quantity desired (see 1.3).

c. Issue of DoDISS to be cited in the solicitation, and if required, the specific issue of individual documents referenced (see 2.2).

d. When first article is required (see 3.2).

e. Number of first article samples required (see 4.3.1).

f. Name and address of the first article inspection laboratory (see 4.3.1).

g. Whether mockup inspection is required or waived (see 3.3 and 4.2).

h. Compartment lighting requirements (see 3.5.5).

i. Whether emergency exit lighting is required (see 3.5.6)

j. Warning signal color (see 3.6.7.8.1).

k. Master caution signal lighting color (see 3.6.7.8.2).

l. Number and type of colors or composite colors to be inspected for color electronic displays (see 4.6.14.2).

6.3 Definitions.

6.3.1 Night Vision Imaging System (NVIS). A system which uses image intensifier tubes to produce an enhanced image of a scene in light conditions too low for normal navigation and pilotage.

6.3.1.1 Direct View Image NVIS (Type I). Any NVIS which uses generation III image intensifier tubes and displays the intensified image on a phosphor screen in the user's direct line of sight.

6.3.1.2 Projected Image NVIS (Type II). Any NVIS which uses generation III image intensifier tubes and projects the intensified image on a see through medium in the user's line of sight. This configuration allows simultaneous viewing of the intensified image and visual cues such as HUD symbology.

6.3.1.3 Class A NVIS. Any NVIS with characteristics as shown on figure 1. Class A NVIS is not compatible with red cockpit lights because of the overlap between the spectrum of red light and the sensitivity of Class A NVIS.

6.3.1.4 Class B NVIS. Any NVIS with characteristics as shown on figure 1. A Class B NVIS is compatible with NVIS Red and therefore is compatible with properly filtered red lights and color electronic displays which meet the requirements of tables III and IV. When specified in table IV, certain components are required to meet Class A NVIS compatibility requirements in order to facilitate interchangeability of equipment.

6.3.2 NVIS lighting compatibility The aircraft interior lighting that provides acquisition of aircraft interior information with the unaided eye without degrading the image intensification capabilities of the NVIS during night flight operations. Conforming to the detailed performance and test requirements specified herein shall be considered as meeting this definition.

6.3.3 Lighting system. All devices that emit or transmit light within the flight deck or other crew compartments.

6.3.4 Lighting subsystem. All devices that emit or transmit light within the flight deck or other crew compartments and are attached to the aircraft power via a common dimmer control.

6.3.5 Crewstation or compartment. All work stations or compartments within the aircraft in which the aircrewmember is required to use NVIS in the performance of duties.

6.3.6 Interior lighting. All lighting within the aircraft including but not restricted to the following lighting systems:

a. Instrument
   - Primary
   - Secondary

b. Console
   - Primary
   - Secondary

c. Emergency

d. Warning, caution, and advisory displays and indicators

e. Utility

f. Controls (knobs, handles, push buttons)

g. Compartment

h. Work and inspection lights

i. Jump lights

6.3.7 CIE color coordinate system. The fundamental definitions of color are expressed in terms of the "standard observer" and coordinate system adopted by the International Commission on Illumination (C.I.E.) at Cambridge, England, in 1931 and published in the Journal of the Optical Society of America, Vol. 23, page 359, October 1933. Wherever chromaticity coordinates (x, *y*, z) appear in this document they relate to this system. The CIE 1976 uniform chromaticity scale (UCS) diagram is the CIE 1931 chromaticity diagram redrawn with the x and y axes subjected to a linear transformation as defined in CIE Publication 15, Supplement 2, 1978.

6.3.8 NVIS radiance. NVIS radiance is the amount of energy emitted by a light source that is visible through NVIS. NVIS radiance is defined as the integral of the curve generated by multiplying the spectral radiance of a light source by the relative spectral response of the NVIS defined in tables VIII or IX as appropriate (see 4.6.12).

6.3.9 Rated drive condition. Rated drive condition(s) are the electrical power state(s) obtained by conformance to the allowable electrical characteristics (voltage, current, pulse width modulation, frequency, etc.) in MIL-STD-704 for the various lighting components or systems in meeting specified lighting levels.

6.3.10 Light leaks. Visual evidence through the NVIS of light emitted from a component from areas which are not intended to be illuminated (non compatible unfiltered light leaks).

6.3.11 Contrast vs contrast ratio. Contrast (C_L, C_I and C_{UL}) as specified in 4.6.14.2.1 is one less than contrast ratio, defined as L_2/L_1 in some specifications.

6.3.12 Electronic and/or electro-optical displays. All displays capable of presenting a variety of different images on their screen; the displayed portrayals being generated through direct electronic modulation or through indirect electro-optical modulation of emitted, transmitted, or reflected light luminance levels, contrasts and/or chromaticities. These displays may present characters, numerals, symbols, graphics, or video. They are based on a CRT, a dot matrix technology, or a segmented design; and may or may not, be capable of portraying shades of gray.

6.4 Rationale. Rationale behind the requirements of this document are available in NADC Report No. 87060-20, Rationale Behind The Requirements Contained in Military Specifications MIL-L-85762 and MIL-L-85762A.

6.5 Subject term (keyword) listing.

chromaticity
console
controls
crewstation lighting
daylight readability
direct image NVIS
display
NVG compatible
projected image NVIS
radiance

6.6 Metrication. The following conversion factors are applicable to this document:

Inches X 25.4 = millimeters (mm)
Foot X 0.3048 = meters (m)
Footlamberts (fL) X 3.426751 = candela per m^2 (cd/m^2) or (NITS)
Footcandles (fc) X 10.76391 = lumens per meter square or lux (lx)

6.7 Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: ASC/ENFC, 2335 Seventh St., Wright-Patterson AFB OH 45433-7809.

APPENDIX A

SPECTRAL RADIANCE, LUMINANCE, AND ILLUMINANCE MEASURING EQUIPMENT

A.1 SCOPE

A.1.1 Scope. This appendix details the requirements of the chromaticity, spectral radiance, luminance, and illuminance measurement equipment to be used when performing measurements in accordance with this document. This appendix is a mandatory part of this document. The information contained herein is intended for compliance.

A.2 APPLICABLE DOCUMENTS

(This section is not applicable to this appendix.)

A.3 SPECTRORADIOMETER

A.3.1 Chromaticity and spectral radiance measurement. Chromaticity and spectral radiance measurements shall be made using a spectroradiometer meeting the requirements herein. The following calibrations and checks shall be performed within the time period specified in order to assure that the spectroradiometer meets the requirements of this specification. Records of how the spectroradiometer calibration was performed, when performed and the standard lamp used shall be maintained by the contractor and shall be available for Government inspection.

A.3.2 Spectroradiometer sensitivity. The spectroradiometer, when assembled as a complete system, shall have sufficient sensitivity to permit measurement of radiance levels equal to or less than that listed in the table below at a half-power band width of 10 nm and a signal to root-mean-square noise ratio of 10:1.

Wavelength	Radiance Level
380 to 600 nm	1.0×10^{-10} W/cm^2 sr nm
600 to 900 nm	1.7×10^{-11} W/cm^2 sr nm
900 to 930 nm	1.0×10^{-10} W/cm^2 sr nm

A.3.2.1 Spectroradiometer sensitivity calibration. Calibration of the spectroradiometer shall be performed within six months (or more frequently if required to insure that the spectroradiometer meets the requirements specified herein) prior to taking a measurement. This calibration shall be traceable to National Institute of Standards and Technology (NIST) standards. The calibrations shall be performed over the wavelength band and at intervals consistent with the measurements to be made. The calibration shall demonstrate that the spectroradiometer meets the sensitivity requirements of A.3.2. A separate calibration must be performed for each spectroradiometer configuration used during tests. For example, a calibration must be performed for each set of optics used, or when filters are used in front of the spectroradiometer.

A.3.3 Wavelength accuracy and repeatability. The wavelength accuracy shall be within ±1.0 nm. The wavelength accuracy is the difference between the wavelength actually being measured and the indicated wavelength. Wavelength repeatability shall be within ±0.5 nm.

A.3.3.1 Wavelength accuracy and repeatability verification. Wavelength accuracy and repeatability shall be verified within one month prior to taking a measurement using a source with known emission lines. As a minimum, the wavelength accuracy and repeatability shall be verified at one point in each 150 nm interval starting with 350 nm and ending with 950 nm. The wavelength accuracy and repeatability check shall be performed using either a scanning or non-scanning technique.

A.3.3.1.1 Scanning technique. If the scanning technique is used, the spectroradiometer shall be utilized to measure the spectral radiance of the source by scanning from below the peak wavelength of the known emission line to be measured to above the peak wavelength in steps no greater than 0.1 nm. This process shall be repeated three times for each emission line that is used for the wavelength accuracy and repeatability test. The spectroradiometer shall be considered to have passed the wavelength accuracy test if, for each measurement, the wavelength of the measured peak is within 1 nm of the actual peak. The spectroradiometer shall be considered to have passed the wavelength repeatability test if, for each emission line tested, the wavelength of the three measured peaks are within 0.5 nm of each other.

A.3.3.1.2 Non-scanning technique. If the non-scanning technique is used, the monochromator shall be positioned to obtain a peak reading for each emission line tested. The wavelength of the peak reading shall be recorded. Each emission line shall be measured three times. During this test the monochromator entrance and exit slit widths shall be no greater than 1 nm. The spectroradiometer shall be considered to have passed the wavelength accuracy test if, for each measurement, the wavelength of the measured peak is within 1 nm of the actual peak. The spectroradiometer shall be considered to have passed the wavelength repeatability test if, for each emission line tested, the wavelength of the three measured peaks are within 0.5 nm of each other.

A.3.4 Current resolution. Where analog to digital (A to D) logic is used in the measurement of the current from the detector, the A to D conversion shall provide at least ±2048 counts of resolution for each measurement scale or the resolution shall be equal to or better than ±0.05% of each measurement scale.

A.3.5 Zero drift. During any given spectroradiometric scan, the maximum zero drift shall be less than 0.2% of the full scale reading on the most sensitive scale, after the appropriate warm up period. A capability shall be provided to allow zero drift to be checked before any given spectroradiometric scan.

A.3.6 Linearity. Within any given measurement scale, the linearity shall be ±1% of the full scale value. The linearity between any two measurement scales shall be ±2%.

A.3.6.1 Linearity verification. The linearity of the spectroradiometer shall be verified within six months prior to taking a measurement. A linearity check shall be performed on each detector used during the test procedures. The spectroradiometer operational parameters shall not be varied during the linearity test. The linearity check shall be performed at a specific wavelength (to be determined by the contractor) which shall not be varied during the linearity test. A light source which can be precisely, mechanically, or optically varied in intensity shall be used for the linearity check. Acceptable methods that may be used to vary the intensity of the light source include the use of neutral density filters (with known transmission), precision apertures, superposition, or the inverse square law (provided the distance between the lamp and spectroradiometer can be precisely controlled using a photometric type bench). Dimming of the lamp through electronic means is unacceptable. The intensity of the lamp shall be adjusted to give a full scale reading on the lowest level of dynamic range of the spectroradiometer. Call the lamp output N and the reading on the spectroradiometer R. The intensity of the lamp shall be varied in accordance with the table below, and, in order to pass the linearity check, the output of the spectroradiometer, over its entire dynamic range (as applicable), shall be within the limits shown below.

Lamp Output	Spectroradiometer Output
0.1N	0.1R ± .01R
0.5N	0.5R ± .01R
5N	5.0R ± 0.2R
10N	10R ± 0.2R
50N	50R ± 2.0R
100N	100R ± 2.0R
500N	500R ± 20R
1000N	1000R ± 20R
5000N	5000R ± 200R
10000N	10000R ± 200R

A.3.7 Signal conditioning. Controls shall be provided to permit the operator to improve or change the signal-to-noise ratio of a measurement.

A.3.8 Stray light. Stray light within the spectroradiometer shall not adversely affect the accuracy of the spectroradiometer when tested in accordance with the procedures herein.

A.3.8.1 Stray light verification. Stray light accuracy shall be verified within a six month period prior to taking a measurement. Stray light accuracy shall be verified by measuring the spectral radiance of a NIST traceable standard of spectral radiance which is filtered by a filter with known transmission that is NIST traceable. The measurement shall be made from 380 to 930 nm in 5 nm increments. The transmission of the filter shall be greater than 50% from 380 to 500 nm and less than 0.2% from 690 to 930 nm (see A.6.1). For the spectroradiometer to pass the stray light test, the measured value of spectral radiance at each wavelength shall be within 5% of the value calculated by multiplying the output of the standard lamp by the transmission of the filter. The stray light shall be checked for each configuration of optics that is used during the testing.

A.3.9 Spectroradiometer optics. If the spectroradiometer is used for luminance measurements, the optics shall be capable of allowing measurements of spot sizes down to .007 in with a full scale sensitivity of 1.0 fL.

A.3.10 Spectroradiometer viewing system. The viewing system shall be capable of locating the spot to be measured with a maximum error of 5% of the diameter of the spot to be measured.

A.3.10.1 Spectroradiometer viewing verification. The accuracy of the viewing system shall be verified prior to taking a test measurement by placing a black card with a hole in front of a light source in such a manner that an aperture in the spectroradiometer optics covers the hole when viewed through the viewing system. The card shall then be moved back and forth in one axis orthogonal to the axis of the spectroradiometer until a peak reading is obtained on the spectroradiometer. The distance (A) the card was moved from its original position to the peak position shall be recorded. The card shall be placed back in its original position and then moved back and forth in the axis orthogonal to the axis of the first movement and orthogonal to the axis of the spectroradiometer until a peak reading is obtained on the spectroradiometer. The distance (B) the card was moved from its original position to the peak position shall be recorded. The viewing system of the spectroradiometer shall be considered to be aligned accurately if both A and B are less than 5% of the diameter of the spot size at the card. The monochromator shall be set at a single wavelength for the entire test. For instruments for which the viewing optics and measuring optics are one in the same, this task is not required.

A.3.11 Spectroradiometer accuracy. The spectroradiometer shall yield a spectral radiance within ±5% of that of a NIST traceable standard of spectral radiance at each 5 nm wavelength throughout the range of 380 nm to 930 nm. When measuring a NIST traceable standard of color temperature or chromaticity, the spectroradiometer shall yield chromaticity coordinates u' and v' within ±0.007 of their respective certificate values.

A.3.11.1 Spectroradiometer accuracy verification The accuracy shall be verified within a six month period prior to taking a test measurement. Verification shall be performed by measuring a NIST traceable spectral standard lamp other than the lamp used to calibrate the spectroradiometer and comparing the measured output to the certified output. The measured spectral radiance at each 5 nm wavelength over the 380 to 930 nm portion of the electromagnetic spectrum and the color coordinates calculated for the standard lamp shall not differ from the certified output by more than that specified in A.3.11.

A.4 PHOTOMETER

A.4.1 Luminance measurement equipment. Luminance measurements can be made using either a spectroradiometer meeting the requirements of A.3 through A.3.11.1 above or a photometer meeting the requirements herein. When a photometer is used as part of the test equipment, the following calibrations and checks shall be verified within a year prior to taking a measurement in order to assure that the photometer meets the requirements of this document. Records of calibrations and checks shall be maintained by the contractor and shall be available for Government inspection.

A.4.2 Photometer calibration. The photometer shall be calibrated using methods that are traceable to NTIS standards.

A.4.2.1 Photometer sensitivity. The full-scale sensitivity shall be 1.0 fL or less, with a spot size of no greater than 0.007 inch.

A.4.2.2 Photometer accuracy. The measured luminance of a NIST traceable luminance standard shall be within ±2% of the NIST certified luminance.

A.4.2.3 Photometer sensitivity and accuracy verification. The full-scale sensitivity and accuracy of the photometer shall be verified using a NIST traceable standard of luminance set to a luminance value less than or equal to 1.0 fL and also equal to the known full-scale sensitivity value of one of the photometer ranges. Using a spot size no greater than 0.007 inch the photometer full scale sensitivity shall be within ±2% of the NTIS traceable standard of luminance value.

A.4.3 Readout resolution. The unit shall have a digital readout with a resolution better than or equal to 0.1% of full scale.

A.4.4 Photometer optics. The optics shall be capable of allowing measurements of spot sizes down to 0.007 inch while meeting the sensitivity requirements of A.4.2.1. The optics shall be capable of focusing to no less than 4.0 inches or less.

A.4.5 Photometer viewing system. The viewing system must be capable of locating the spot to be measured with a maximum error of 0.002 inch.

A.4.5.1 Photometer viewing system verification. A black card, with a hole in the center, shall be placed in front of a light source in such a manner that the smallest aperture of the photometer optics covers the hole when viewed through the viewing system. The card shall be moved bark and forth in one axis orthogonal to the axis of the photometer until a peak reading is obtained on the photometer. The distance (A) the card was moved from its original position to the peak position shall be recorded. The card shall be placed back in its original position and then moved back and forth in the axis orthogonal to the axis of the first movement and orthogonal to the axis of the photometer until a peak reading is obtained on the photometer. shall be no greater than 1%. The distance (B) the card was moved from its original position to the peak position shall be recorded. The viewing system of the photometer shall be considered to be aligned accurately if both A and B are less than or equal to 0.002 inch. For instruments in which the viewing aperture and measuring aperture are one in the same, this test is not required.

A.4.6 Photometer polarization error. The polarization error shall be no greater than 1%.

A.4.6.1 Photometer polarization error verification. The polarization error shall be checked by placing a linear polarizer in the optical path between the standard lamp and the photometer and then measuring the luminance. The polarizer shall be rotated 45° and another measurement shall be made. The polarizer shall be rotated another 45° and another measurement shall be made. The photometer shall be considered as having passed the polarization error test if the difference between the three measurements is lower than or equal to the percent error specified in A.4.6. Throughout the test the alignment of the standard lamp shall not be changed. The transmission of the linear polarizer shall be greater than or equal to 20%, and the transmission of two pieces of the polarizer material, when oriented so that the direction of polarization of the two pieces are at right angles, shall be less than or equal to 0.1%.

A.4.7 Colorimetry. When colorimetry capability is required, the photometer shall be calibrated to measure the NVIS color for the application (i.e., NVIS Green A, NVIS Green B, NVIS Yellow or NVIS Red). The calibration shall be traceable to NIST standards.

A.5 REFLECTANCE STANDARD

A.5.1 Reflectance standard. The reflectance standard shall have a lambertian reflecting surface with reflectivity greater than 90% from 380 nm to 930 nm. The length and width of the reflecting surface shall be at least 2 inches by 2 inches.

A.5.1.1 Reflectance standard verification. The reflectance of the reflectance standard shall be measured within a six month period prior to each test. The measured reflectance shall be used as a calibration figure whenever the reflectance standard is used. The measurement of the reflectance shall be traceable to NIST standards. The reflectance standard shall be calibrated using the same orientation as that used in 4.6.11 and 4.6.12.

A.6 NOTES

A.6.1 Filter. A 0.12 inch thick piece of Schott BG-23 or equivalent should meet the transmission requirements of A.3.8.1.

APPENDIX B

SAMPLE CALCULATIONS

B.1 SCOPE

B.1.1 Scope. This appendix contains sample calculations used to determine compatibility with type I, class A NVIS. This appendix is not a mandatory part of this document. The information contained herein is intended for guidance only. The following sample calculations are based upon data obtained during the measurement of one particular lighting component, an advisory signal to be used with type I, class A equipment. The chromaticity coordinates and NVIS radiance values derived from the following sample calculation apply to this particular device only.

B.2 APPLICABLE DOCUMENTS

(This section is not applicable to this appendix.)

B.3 NVIS RADIANCE CALCULATIONS. As specified in table IV, the required luminance level for NVIS radiance, L_r, for advisory signals is 0.1 footlamberts (fL). As specified in 4.7.14.1 the luminance of the lighting component at rated drive conditions, L_m, was measured by the spectroradiometer to be 1.7839 fL. From this information a scaling factor can be generated using Formula 13:

$$S = \frac{L_r}{L_m} = \frac{0.1\text{fL}}{1.7839\text{fL}} = 5.605695 \times 10^{-2} \qquad \text{(Formula 13)}$$

Where:

S = scaling factor

L_r = required luminance level for NVIS radiance

L_m = luminance measured by the spectroradiometer

Figure B-1 is a plot of the spectral output of the signal when it is energized to produce 1.7839 fL. NVIS radiance is then calculated using Formula 14a:

$$\text{NVIS radiance} = S_{max} \int_{450}^{930} G_A(\lambda)\, N(\lambda)\, d\lambda \quad NR_A \qquad \text{(Formula 14a)}$$

Where:

$G_A(\lambda)$	=	relative NVIS response (see table VIII)
S	=	5.605695×10^{-2}
$N(\lambda)$	=	spectral radiance of lighting component (W/cm^2 sr nm) (see figure B-1)
$d\lambda$	=	5nm

NOTE: On figure B-1, the units of radiance are ($\mu W/cm^2$ sr nm). To obtain the correct units of radiance for Formula 14a, the values on figure B-1 must be multiplied by 1.0×10^{-6}.

Performing the above calculation yields an NVIS radiance for this component of 4.73613×10^{-11} NR_A. This component conforms to the requirement of table IV to be not greater than 1.7×10^{-10} NR_A for Class A equipment.

B.4 CHROMATICITY CALCULATIONS. As specified in table III chromaticity measurements shall be conducted on advisory signals when the component is energized to produce 0.1 fL. Figure B-2 is a plot of the spectral output of the signal when it is energized to produce 0.1 fL. From 4.7.13, Formulas 5, 6 and 7 are used to calculate the following tristimulus values for this signal.

$X = 1.90229 \times 10^{-7}$

$Y = 5.12926 \times 10^{-7}$

$Z = 8.47261 \times 10^{-9}$

These tristimulus values are then used to calculate the 1931 C.I.E. chromaticity coordinates using Formulas 8 and 9.

$x = 0.241443791$

$y = 0.651019551$

These 1931 C.I.E. Chromaticity coordinates are then used to calculate the 1976 UCS chromaticity coordinates using Formulas 10 and 11.

$u' = 0.0935$

$v' = 0.5672$

When substituted into Formula I of 3.10.8, the 1976 UCS chromaticity coordinates indicate that this particular lighting component meets the requirements of table III for “NVIS GREEN A” type I, class A compatible equipment.

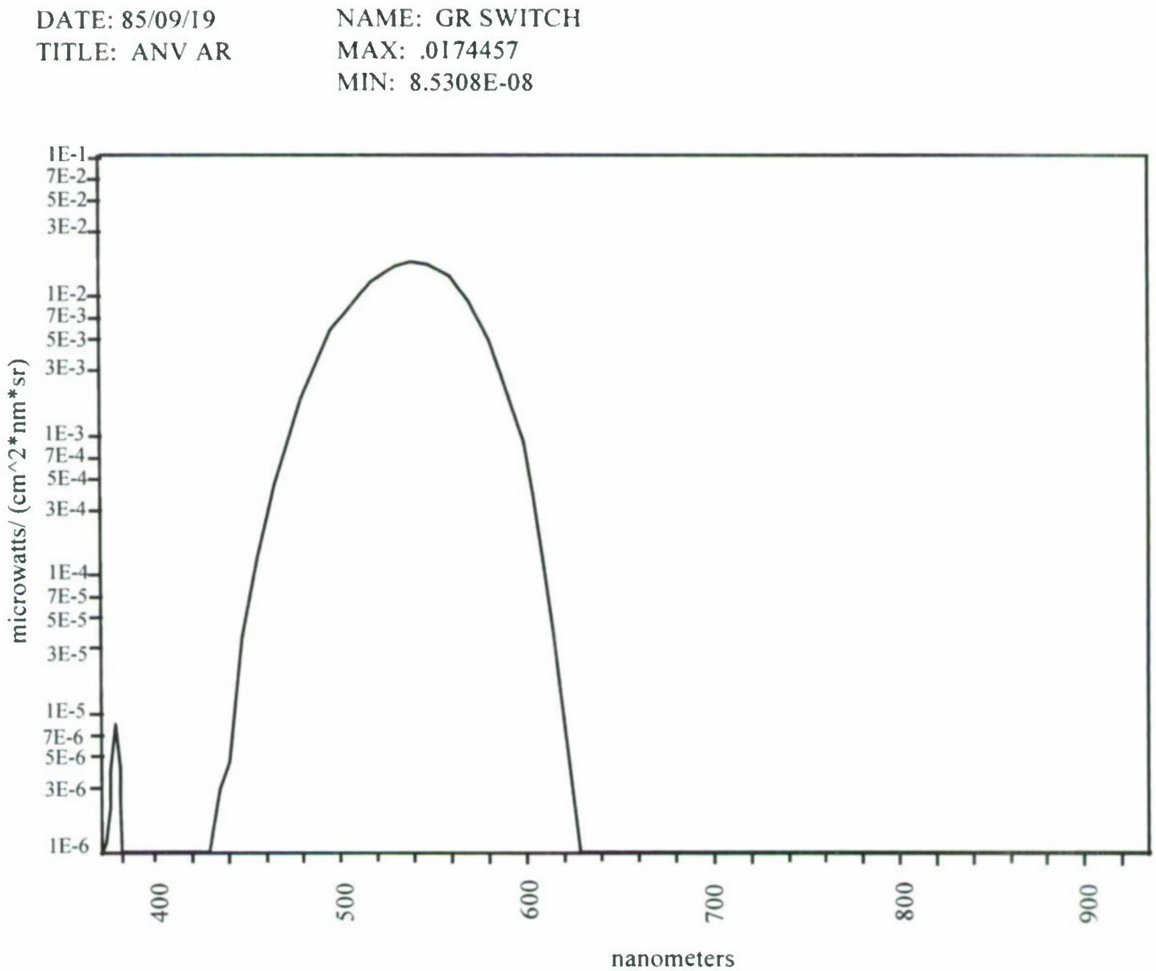
$$(u' - u'_1)^2 + (v' - v'_1)^2 \leq (r)^2 \qquad \text{(Formula 2)}$$

Where:

$u'_1 = .088$ (see 3.10.8.6)

$v'_1 = .543$ (see 3.10.8.6)

$r = .037$ (see 3.10.8.6)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TITLE: ANV AR
NAME: GR SWITCH
MAX: .0174457
MIN: 8.5308E-08
1E-1
7E-2
5E-2
3E-2
1E-2
7E-3
5E-3
3E-3
1E-3
7E-4
5E-4
3E-4
1E-4
7E-5
5E-5
3E-5
1E-5
7E-6
5E-6
3E-6
1E-6
microwatts/ (cm^2*nm*sr)
400
500
600
700
800
900
nanometers

FIGURE B-1. Spectral output of example signal at rated drive conditions (1.7839fL).

370	7.3754E-07	510	1.2119E-02	650	8.5490E-08	790	1.3246E-07
375	9.6851E-06	515	1.3788E-02	655	8.5535E-08	795	1.3643E-07
380	3.3755E-07	520	1.5080E-02	660	8.5803E-08	800	1.4055E-07
385	2.3725E-07	525	1.6328E-02	665	8.5849E-08	805	1.4477E-07
390	1.8954E-07	530	1.7123E-02	670	8.6139E-09	810	1.4937E-07
395	1.6962E-07	535	1.7446E-02	675	8.6493E-08	815	1.5412E-07
400	1.5954E-07	540	1.7171F-02	680	8.7098E-08	820	1.5889E-07
405	1.5383E-07	545	1.6200E-02	685	8.7658E-08	825	1.6421E-07
410	1.4772E-07	550	1.4850E-02	690	8.8377E-08	830	1.6918E-07
415	1.4203E-07	555	1.3188E-02	695	8.9149E-08	835	1.7419E-07
420	1.3855E-07	560	1.1186E-07	700	9.0129E-08	840	1.7931E-07
425	1.3974E-07	565	9.1515E-03	705	9.1054E-08	845	1.8455E-07
430	2.9100E-06	570	7.0494E-03	710	9.2189E-08	850	1.9024E-07
435	4.6091E-06	575	5.1191E-03	715	9.3707E-08	855	1.9635E-07
440	2.2454E-05	580	3.4680E-03	720	9.5104E-08	860	2.0274E-07
445	6.0578E-05	585	2.1926E-03	725	9.6411E-08	865	2.0992E-07
450	1.1215E-04	590	1.2660E-03	730	9.7374E-08	870	2.1766E-07
455	2.4485E-04	595	6.6028E-04	735	9.7622E-08	875	2.2633E-07
460	4.5484E-04	600	3.0882E-04	740	9.5771E-08	880	2.3628E-07
465	8.2161E-04	605	1.1893E-04	745	9.4317E-08	885	2.4891E-07
470	1.3433E-03	610	4.3606E-05	750	9.6128E-08	890	2.6236E-07
475	2.1281E-03	615	1.2054E-05	755	1.0155E-07	895	2.7604E-07
480	3.1192E-03	620	3.9837E-06	760	1.0799E-07	900	2.8953E-07
485	4.3367E-03	625	8.6170E-08	765	1.1334E-07	905	3.8283E-07
490	5.7409E-03	630	8.5718E-08	770	1.1777E-07	910	3.1601E-07
495	7.2920E-03	635	8.5459E-08	775	1.2149E-07	915	3.2946E-07
500	8.8926E-03	640	8.5308E-08	780	1.2519E-07	920	3.4522E-07
505	1.0478E-03	645	8.5455E-08	785	1.2876E-07	925	3.6457E-07
						930	3.8781E-07

FIGURE B-1. Spectral output of example signal at rated drive conditions (1.7839fL) - Continued.

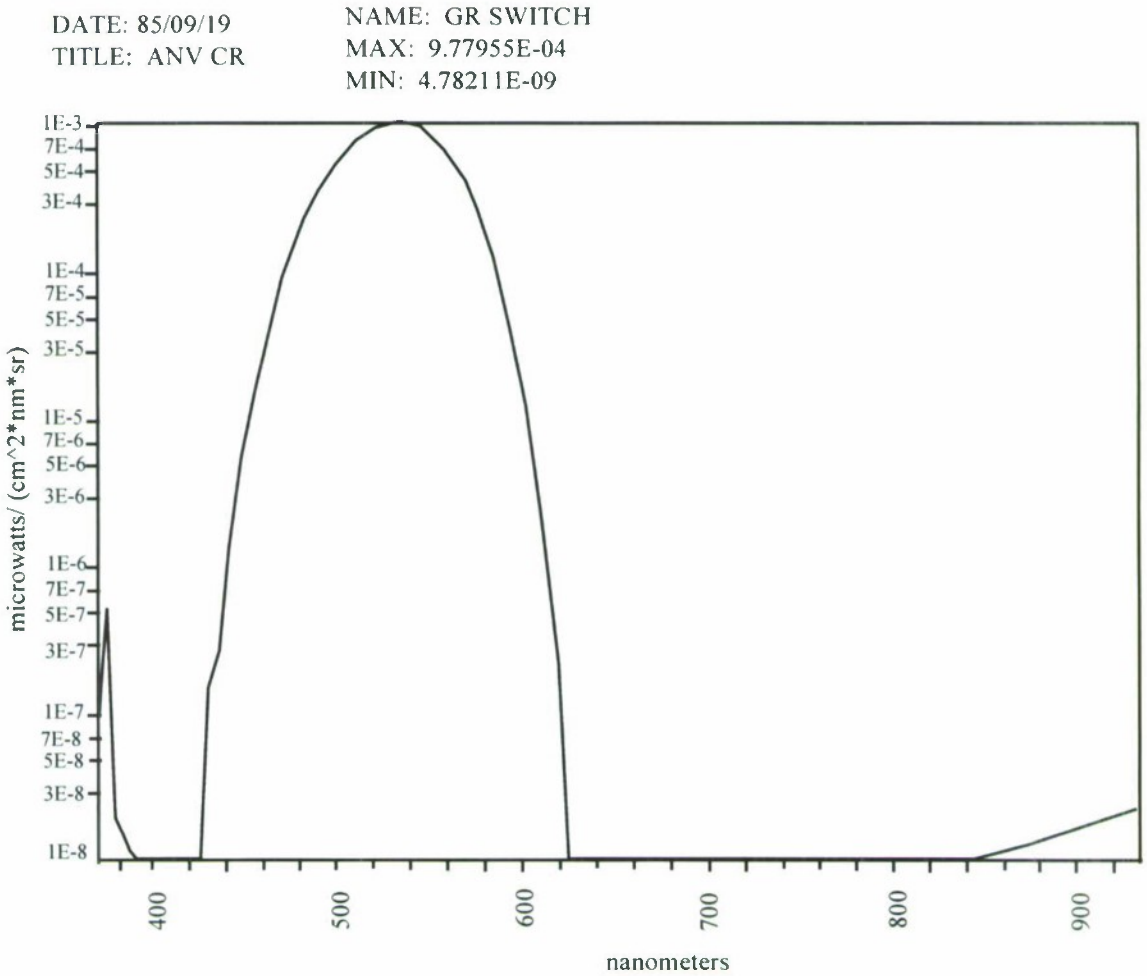

FIGURE B-2. Spectral output of example signal at 0.1 fL.

370	4.1344E-08	515	7.7290E-04	660	4.8099E-04	805	8.1152E-09
375	5.4292E-07	520	8.4535E-04	665	4.8124E-09	810	8.3734E-09
380	1.8922E-08	525	9.1528E-04	670	4.8287E-09	815	8.6396E-09
385	1.3299E-08	530	9.5984E-04	675	4.8485E-09	820	8.9070E-09
390	1.0625E-08	535	9.7796E-04	680	4.8824E-09	825	9.2053E-09
395	9.5086E-09	540	9.6253E-04	685	4.9138E-09	830	9.4840E-09
400	8.9434E-09	545	9.0811E-04	690	4.9541E-09	835	9.7644E-09
405	8.6230E-09	550	8.3245E-04	695	4.9974E-09	840	1.0051E-08
410	8.2810E-09	555	7.3926E-04	700	5.0524E-09	845	1.0345E-08
415	7.9616E-09	560	6.2707E-04	705	5.1042E-09	850	1.0664E-08
420	7.7668E-09	565	5.1300E-04	710	5.1678E-09	855	1.1007E-08
425	7.8335E-09	570	3.9517E-04	715	5.2529E-09	860	1.1365E-08
430	1.6313E-07	575	2.8696E-04	720	5.3312E-09	865	1.1767E-08
435	2.5837E-07	580	1.9440E-04	725	5.4045E-09	870	1.220IE-08
440	1.2587E-06	585	1.2291E-04	730	5.4585E-09	875	1.2688E-08
445	3.3958E-06	590	7.0971E-05	735	5.4724E-09	880	1.3245E-08
450	6.2867E-06	595	3.7013E-05	740	5.3686E-09	885	1.3953E-08
455	1.3726E-05	600	1.7312E-05	745	5.2871E-09	890	1.4707E-08
460	2.5497E-09	605	6.6671E-06	750	5.3887E-09	895	1.5474E-08
465	4.6057E-05	610	2.4444E-06	755	5.6928E-09	900	1.6230E-08
470	7.5304E-05	615	6.7572E-07	760	6.0537E-09	905	1.6976E-08
475	1.1930E-04	620	2.2331E-07	765	6.3536E-09	910	1.7715E-08
480	1.7485E-04	625	4.8304E-09	770	6.6017E-09	915	1.8468E-08
485	2.4310E-04	630	4.8051E-09	775	6.8102E-09	920	1.9352E-08
490	3.2182E-04	635	4.7906E-09	780	7.0176E-09	925	2.0437E-08
495	4.0877E-04	640	4.7821E-09	785	7.2177E-09	930	2.1740E-08
500	4.9849E-04	645	4.7903E-09	790	7.4253E-09		
505	5.8734E-04	650	4.7923E-09	795	7.6479E-09		
510	6.7938E-04	655	4.7948E-09	800	7.8787E-09		

FIGURE B-2. Spectral output of example signal at 0.l fL - Continued.

APPENDIX C

DEFINITIONS OF CLASSES OF NVIS COMPATIBLE AIRCRAFT EXTERIOR LIGHTING

C.1 SCOPE.

C.1.1 Scope. Efforts are under way on numerous projects to make the exterior lighting on aircraft NVIS compatible. A common problem has been definitions - one person thinks "compatible" means it can be seen with NVIS but not with the naked eye, while another thinks "compatible" means it can be seen with the naked eye but will have little or nor effect on NVIS. This appendix is not a mandatory part of this document. The information contained herein is intended for guidance only. A proposed set of compatibility definitions is provided below.

C.2 APPLICABLE DOCUMENTS

(This section is not applicable to this appendix.)

C.1 DEFINITIONS

C.1.1 Secure. An Army definition, often applied to ground vehicles and equipment, meaning that the visible light emitted is reduced to the minimum needed to do the mission, and the near IR content is reduced to less than TBD percent of the visible light.

C.1.2 Friendly. Exterior lighting that is fully useable by people without NVIS (i.e, typically meets FAA requirements for visibility) but has drastically reduced IR content so that it can be used while flying formation with aircraft in which NVIS are being used (for example, going to and from a training site through civilian airspace.)

C.1.3 Covert - IR lights. Typically filtered so they are not visible to the naked eye beyond a few tens of feet, intended to provide illumination so that NVIS will work without adequate natural light.

APPENDIX D

LEAKY GREEN NVIS DEFINITION

Some aircraft have HUDs that use a hologram as the reflective element in the combining glass. Holograms typically only work with one wavelength of light - this feature can be used to improve the efficiency and see-through clarity of the HUD, but it means the light coming from the HUD is concentrated at one wavelength. Since this wavelength is in the green part of the spectrum and is blocked by the minus blue filter in the NVIS, it is nearly impossible to see a holographic HUD with Class A or B NVIS. Consequently, modified NVIS have been built and tested which have a "notch" or "leak" in the green part of the spectrum. An example of a spectral plot from a leaky green goggle is shown on figure D-1.

Note that MIL-L-85762B addressed this concern by stating a minimum NR requirement for HUDs, but holographic HUDs do not meet this minimum. It is now believed that it is more cost effective to modify the NVIS (adding the green leak) than it is to modify the design of the HUDs (with their inherently single wavelength hologram) to solve this problem. The desire to see the HUD through the NVIS, rather than with the naked eye has also increased due to the improved resolution of new NVIS devices.

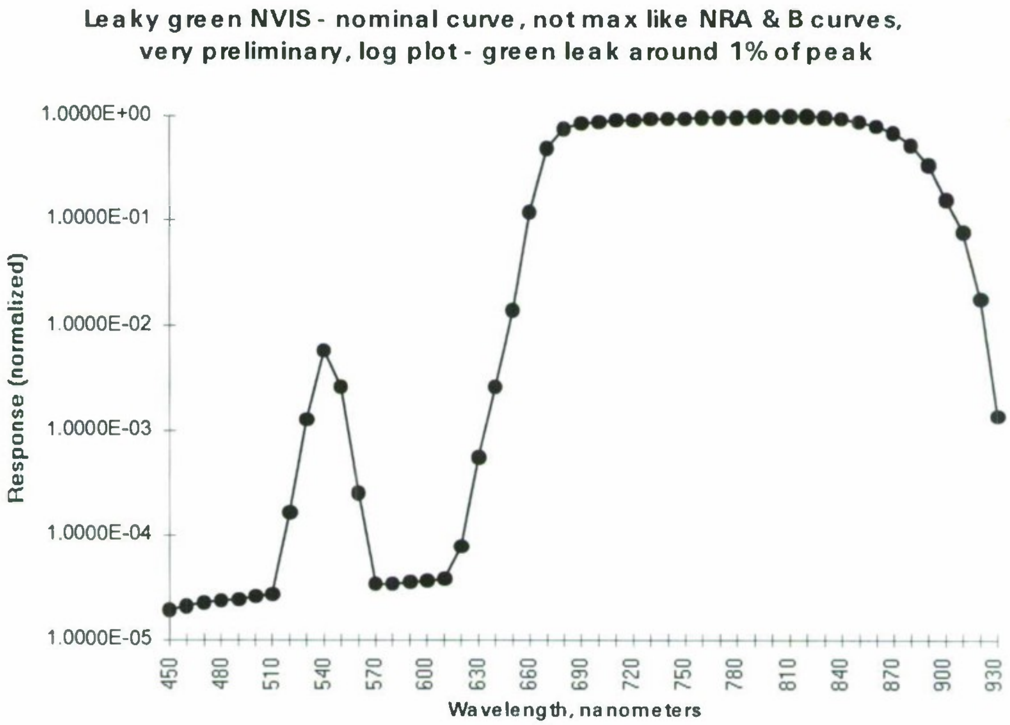

FIGURE D-1. Leaky green NVIS characteristic.